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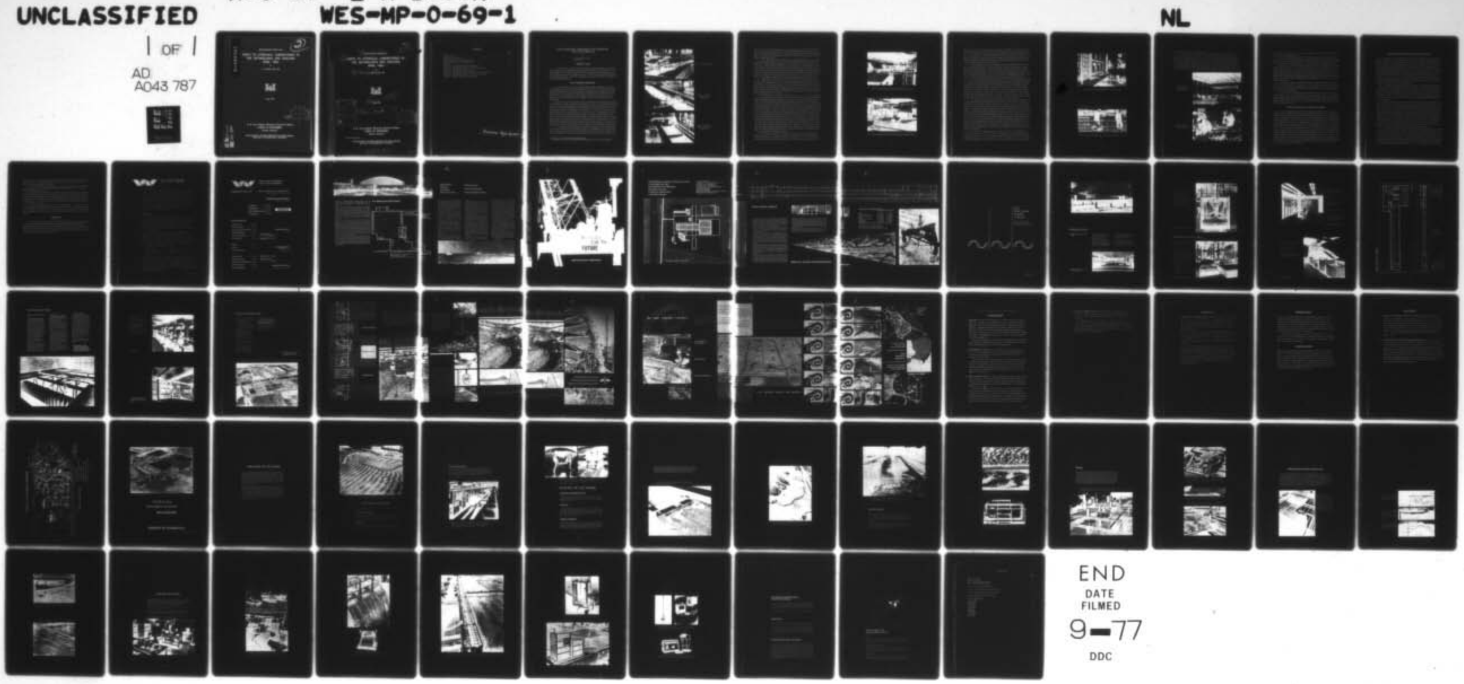

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VISITS TO HYDRAULIC LABORATORIES IN THE NETHERLANDS AND ENGLAND APRIL 1969

by

L. A. Brown, COL, CE

August 1969

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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U. S. Army Engineer Waterways Experiment Station
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VISITS TO HYDRAULIC LABORATORIES IN THE NETHERLANDS AND ENGLAND, APRIL 1969

by

Levi A. Brown, COL, CE*

PURPOSE OF VISITS

1. In order to observe, compare, and study the organization, physical facilities, and type projects under investigation at other hydraulic laboratories performing work similar to that being done at the U. S. Army Engineer Waterways Experiment Station, the Director requested and obtained permission from the Chief of Engineers to visit the Delft Hydraulics Laboratory in the Netherlands and the Hydraulics Research Station, Wallingford, England, in April 1969. Arrangements for the visits were made by correspondence to the Directors of these laboratories.

DELFT HYDRAULICS LABORATORY

2. On 16 April 1969 at 11:00 a.m. I departed Vicksburg and by a combination of Government car and airplane transport arrived in Amsterdam, Netherlands, at 11:00 a.m. 17 April, almost three hours behind the scheduled arrival time. I took an airport bus to the Hague where I was met by Mr. A. Paape, head of the laboratory element in Delft. We had lunch at the Wilhelmina Hotel in Delft where we were joined by Mr. J. E. Prins, Deputy Director, Delft Hydraulics Laboratory. Because of my late arrival Mr. Paape had to leave immediately after lunch. Appendix A** describes and gives the organization of the laboratory.

3. Mr. Prins took me to the new facilities recently constructed for the Delft Hydraulics Laboratory on the outskirts of the campus of the Delft Technical Institute. There we toured the Rijnmond tidal model which is a large indoor, fixed-bed tidal model of the approach to the harbor of Rotterdam (see Appendix B and figs. 1-3). The model is constructed at a horizontal scale of 1 to 640 and a vertical scale of 1 to 64. The model was exceptionally well equipped. The concrete portions of the model were painted yellow for the dry land, the sea portion was painted black to accentuate the contrast in photographs taken of floating objects used in velocity measurements. The instrumentation was modern and of exceptionally fine appearance. The parts were either chrome plated or finished as a well-made camera case might be. The tidal generators were of the spilling weir variety with each spilling weir section of approximately 10 ft in length being individually programmed and controlled by paper tape instructions in control rooms. Data on water-surface elevations, currents, and salinities were sensed by electronic instrumentation and recorded in inclosed control rooms. The recording in general was done by continuous lines on oscillographs or rolls of paper.

4. Also included in the same building with the model of Rotterdam was a large tidal salinity flume 101.5 meters long, 0.672 meters wide and 0.50 meters deep. It was equipped with a 6- by 8-meter tidal basin, tide generating mechanisms at both the seaward and the upstream end, a system to introduce fresh water at the upstream end and remove it at the seaward end, and a system to maintain a constant salinity

* Director, U. S. Army Engineer Waterways Experiment Station.
** The appendices to this report consist of pamphlets and booklets given to the author at Delft and Wallingford.

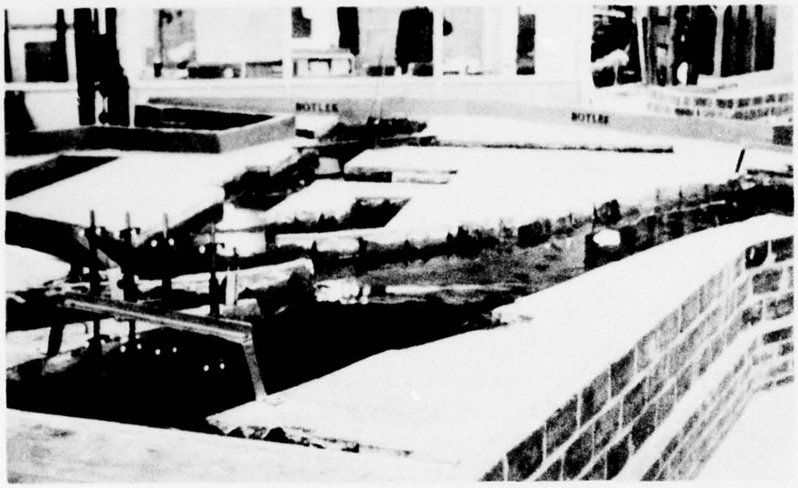


Fig. 1. Rotterdam model

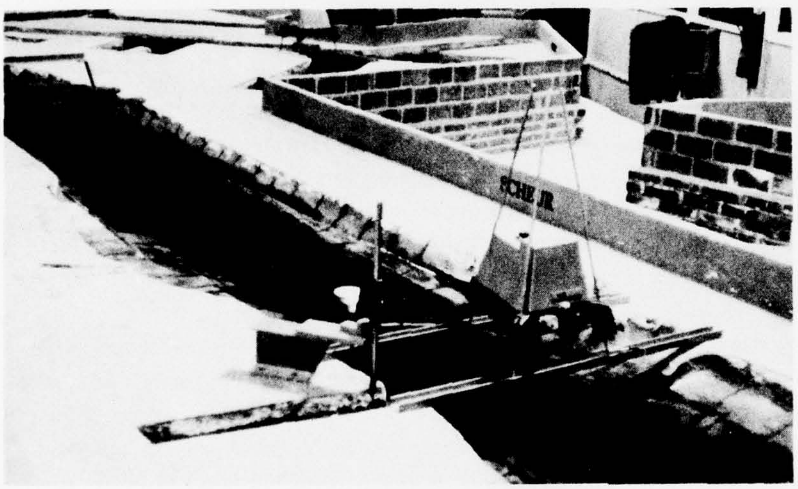


Fig. 2. Stage measuring device, Rotterdam model

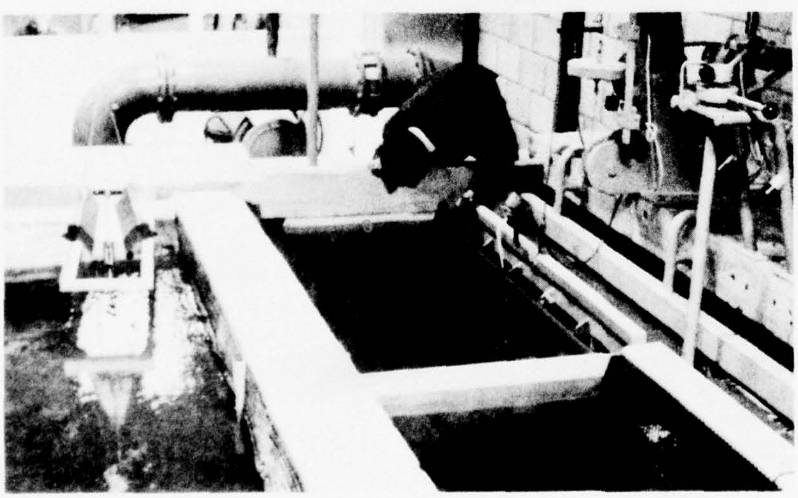


Fig. 3. Spilling weir tide generator, Rotterdam model

in the sea. The objectives of the flume study were to determine means to improve the reproduction of salinity intrusion in a distorted hydraulic model as the Rotterdam Harbor model, and to improve the capabilities of carrying out tidal computations for conditions of nonhomogeneous flow. Mr. Frank Herrmann, engineer at the Waterways Experiment Station, had used this flume while doing graduate work at the Delft Technical Institute in 1967-1969.

5. After visiting the tidal model and salinity flume, I accompanied Mr. Prins on a tour of the new two million dollar wind-wave flume facility in the same compound as the Rotterdam Harbor model. The facility has two wind-wave flumes (see Appendix C). The large flume is about 100 meters long, 8 meters wide measured on the waterline, and 10 meters wide on the air profile. It is connected with a wave basin 10 by 25 square meters. The small wind-wave flume is about 100 meters long and 2 meters wide measured on the water. The facility is quite modern and has excellent instrumentation to program random type waves into the flume. These waves are sustained by the wind blowing over the surface of the water. The waves attack various model sections in the flume. The characteristics of the waves, their frequency, their height, and their energy are measured and recorded by quite sophisticated electronic instrumentation.

6. After leaving the wind-wave flume we went to the old Delft Hydraulics Laboratory facilities in the center of Delft. There I met Mr. H. J. Schoemaker, the Director. After a brief discussion with Mr. Schoemaker, I toured the facilities in the old laboratory building (figs. 4-5) with Mr. Prins; we reviewed numerous flumes, lock-filling devices for forces on valves, a saltwater controlling lock study for which the prototype lock has been completed within the last six months, and a small wind tunnel constructed of plywood. Operations in this older facility are being phased down as the newer facilities are being constructed near the Delft Technical Institute just outside of Delft and as increased facilities are being constructed at the De Voorst Laboratory in the NE polder.

7. That evening I went to the home of Mr. Schoemaker for dinner. After dinner we had an extensive discussion about the operation of hydraulics laboratories. I found we had many common problems in funding, management, and technical investigations. The split operation of the Delft Hydraulics Laboratory is due to the availability of large areas of land in the NE polder, and originally a plan that the Belgians would share the cost of this new facility which they did not continue to do for very long. Mr. Schoemaker expressed concern in the use of mathematical models in lieu of hydraulic models since he felt that the engineer would lose his ability to have a feel for what is happening and to properly use judgment. He pointed out that in the selection of a model scale, which is done arbitrarily based on judgment and which will provide a model that will produce what has occurred historically that has been observed and recorded, we assume that modifications that are made will produce proper changes in the model. There is the hazard that unobserved relationships will be of importance and that the scaling will not be proper. He gave as an example the presence of littoral currents combined with offshore waves perpendicular to the littoral currents in a model study of a breakwater off the coast of Israel in which he had participated. Mr. Schoemaker noted that velocities do not add vectorially in distorted models because the scaling laws are in a quadratic relationship. Mr. Schoemaker noted that his models were not cheap. In fact, in his words his models were lavish. The models at the British Hydraulics Research Station at Wallingford were, in Mr. Schoemaker's opinion, generally less expensive than those in Delft. I found Mr. Schoemaker to be a delightful conversationalist with great depth of knowledge and perception.

8. On 18 June I was driven from the Hague to the De Voorst Laboratory in the NE polder (Appendix D) by Mr. J.G.H.R. Diephuis, Head of the Site Investigations Service of the Delft Hydraulics Laboratory. While enroute to the De Voorst Laboratory, Mr. Diephuis explained the operations of his Site Investigations Service organization (see Appendix A). Their engineers might be in the field for as

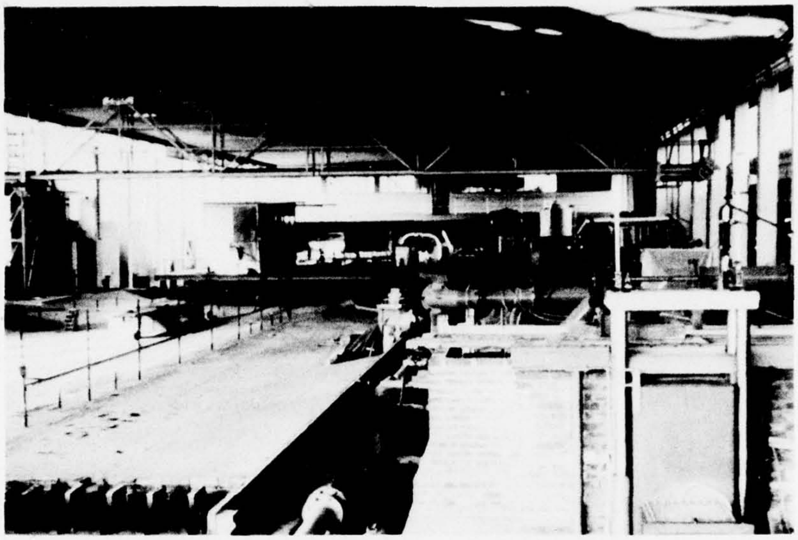


Fig. 4. Interior, old laboratory hall, Delft Hydraulics Laboratory

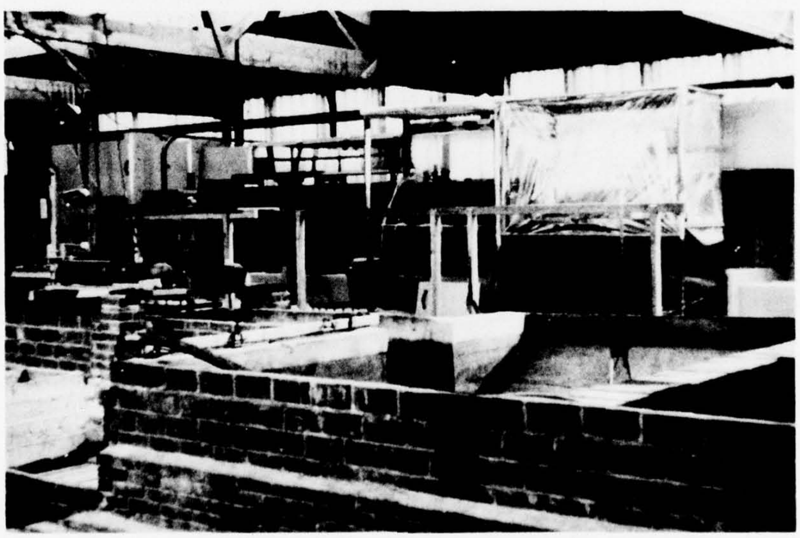


Fig. 5. Plywood wind tunnel, old laboratory hall, Delft Hydraulics Laboratory

long as one year at a time collecting prototype data on currents, tide heights, salinity, waves, and other data needed for the verification of the hydraulic model. He noted that in the area of determining the direction of a wave they still were encountering problems, that sometimes radar was of use but mostly this was done by visual techniques. Mr. Diephuis also noted that there was price competition in soliciting bids from hydraulic laboratories for model studies for projects in underdeveloped countries. In several instances an underdeveloped country has requested a proposal from several hydraulics laboratories in Europe and has selected the laboratory with the lowest price to do the job.

9. At the Laboratory De Voorst I was escorted by Mr. D. Gersie, Deputy Head, for most of my visit. The Laboratory De Voorst has over 300 acres of land. The original concept was that the model studies would be done in the open air. However, the present trend is to enclose the models in buildings to allow for uninterrupted operation. I toured the wind-wave flume (Appendix E) which is a smaller scale facility than the new wind-wave flume in Delft. We also viewed the high-discharge flume (Appendix E). We visited several open-air hydraulic models. In one of the models, the movable-bed material was of a granular plastic and Mr. Gersie said that they had had excellent results with the granular plastic material.

10. In touring the facilities at the Laboratory De Voorst, I viewed a river model with sand as a movable bed. There was at the same model a drying and screening facility to provide sand of the proper gradation. Another model on bed-load transport was studying the effect of different modeling material on the roughness factor. It is planned to surface the river bottom with a particular size aggregate to minimize scour and reduce maintenance dredging. There were two rather large models of a canal intersecting the Rhine River. The smaller model was of a movable-bed type. The larger model of the same area was of a fixed-bed type and allowed man-carrying model tows to be operated within the model. Another channel model had a granular plastic bed material as the movable bed. In a model in which the closing of caissons was being studied, the wind had a very marked effect in spite of tarpaulins being used as windbreaks. The operation of the model had stopped because of the wind on the day that I was present.

11. After visiting several open-air models I discussed the use of mathematical models with Mr. C. B. Vreugdenhil, mathematician. Mr. Vreugdenhil said that they used mathematical models for preliminary investigations, for rough, quick approximations without much cost involved. In some cases, the study will be almost entirely mathematical, as in water hammer studies for pumps, in the regulation of water levels in polders, in drainage canals and networks, discharges into the sea affected by tides, flood waves and river regulation. The mechanism of sediment transport is not known on a large scale; however, there are empirical transport formulas that will give good comparison with models. For some of the tidal models they will use a two-dimensional (horizontal shape) mathematical model to determine the seaward boundary of the hydraulic model. The Laboratory De Voorst has had no experience in hurricane surge modeling since they do not have a need for this in Holland which has no hurricanes. Mathematical modeling has been used in some cases for wave phenomena and refraction of waves within harbors for the first estimate of what will happen. In the area of density currents in estuaries they have used some two-layer models that are crude approximations of the interchange of salt and fresh water. The computers available to the laboratory include a CDC 3200 with 32K of memory at the NE polder and in Delft they have access to an IBM 360-65 at the technical university.

12. On visiting the instrumentation facility at Laboratory De Voorst, I was shown a Hewlett-Packard A-D recorder and converter that can handle up to 100 channels and take 40 readings per second to six significant figures. For much of the recording of information in the past, they have used analog recorders, eight recorders at 12 channels each, that are located in the buildings with the model. They have found that this equipment is not cheap, but that they may increase production on the model and obtain

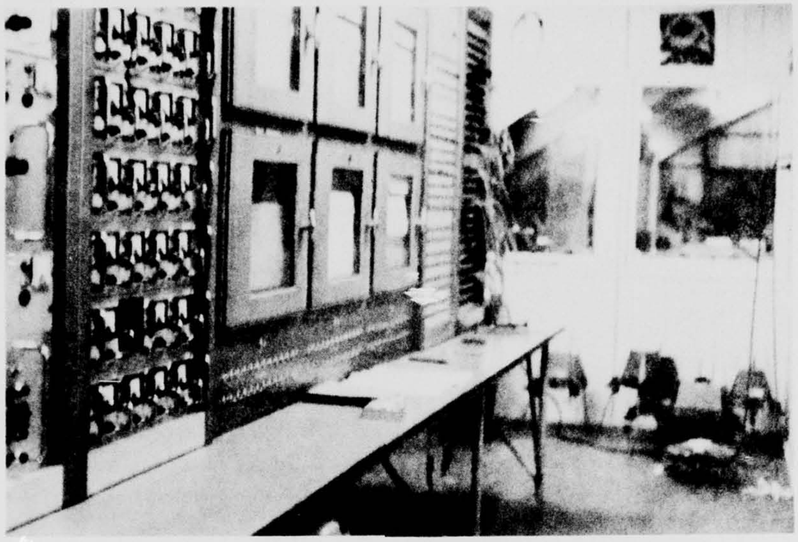


Fig. 6. Control and recording console, Laboratory De Voorst

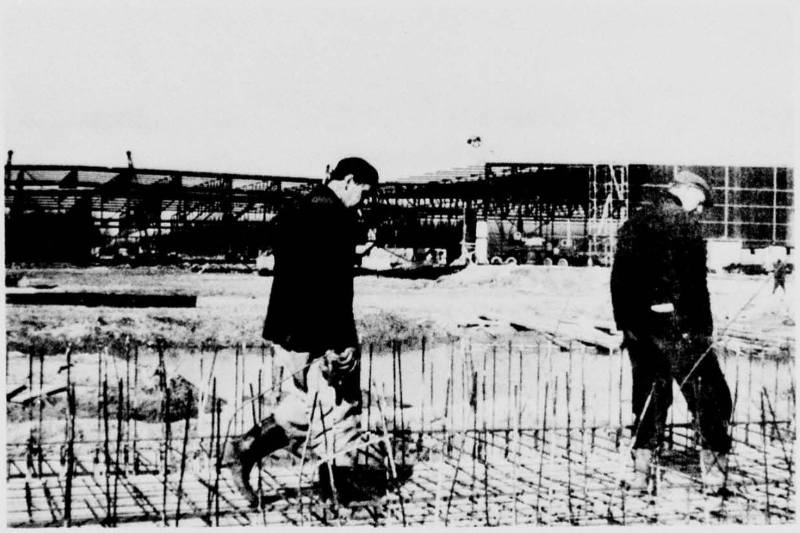


Fig. 7. Six-acre model shelter under construction at Laboratory De Voorst

the results faster, hence allowing more studies to be run.

13. Later in the day we were joined by Mr. J. J. Vinje, Head of the Laboratory De Voorst. We visited a large new model under construction that will be enclosed in a shelter six acres in area (fig. 7). The model is to investigate closure procedures for one of the closures at the mouth of the Rhine River. No density currents will be involved. This study will first use a 1-to-400 fixed-bed general model and later a 1-to-80 movable-bed model of critical areas. They estimate that the model will be in use for nine years. While viewing the model construction I was able to notice their model construction technique (figs. 8-9), which consists of shaping the hardpan clay natural ground into the rough contours of the model, driving wooden pegs with a nail on top to the exact surface elevation of the model, and then filling in to

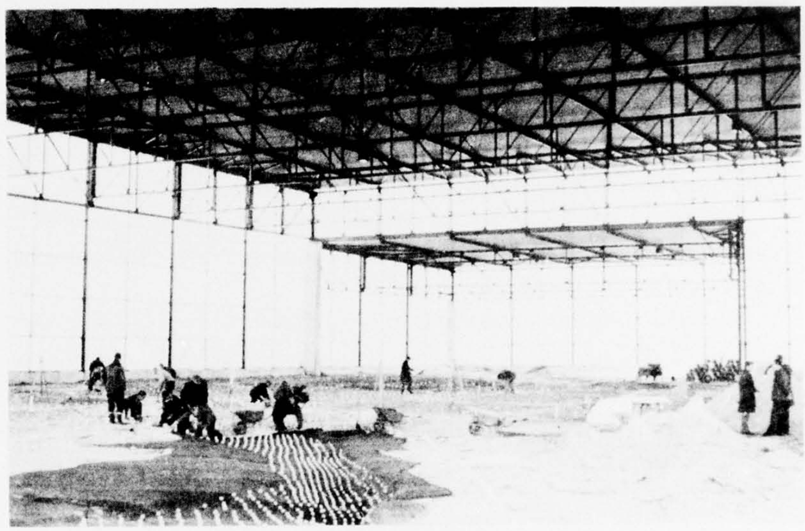


Fig. 8. 1:400 model under construction, Laboratory De Voorst

Fig. 9. Model construction, Laboratory De Voorst

an approximate 3-in.-thickness with a black-colored sand-cement mortar. The movable-bed material that they plan to use will be granular plastic.

14. We later visited two indoor models in hangar-type shelters similar to our aircraft hangars at Vicksburg. In these models coriolis generating devices (Appendix D) were being used to duplicate currents caused by the coriolis effect. It was felt that the coriolis effect was significant in the models in which they were being used; in most of their model studies, however, coriolis effect was not considered significant.

15. During the tour of the tidal models in the hangar-type shelters, I learned that one of the tidal models required the coriolis devices for verification. However, they were not sure if the devices were required in the second model. Since a doubt existed, the coriolis devices were purchased and installed. It was the opinion of Mr. Vinje that the devices were not needed in the second model. However, he did not regret having gotten them since he did plan to use them in his large six-acre model that was under construction. The two tidal models had paper-tape-programmed spilling weirs for tidal generators. Recording of data was by automatic electronic recording devices. In the shelter there was also a towing tank for calibration of instruments.

16. Several times during my tour of the Delft laboratories I asked if they had noticed any effect of temperature on bed movement or sediment transport. Several of their engineers were familiar with the article by Mr. John J. Franco on "Temperature Effects on River Discharges." These same engineers had noted the effects on model operation in cold weather; however, they had done no specific testing to determine the precise effect of temperature.

17. The total number of employees of the Delft Hydraulics Laboratory has been increasing at a rate of about 10% per year for the past several years. In 1966 they employed 339; in 1967, 398. Their present estimated strength is approximately 440 employees. Of these, 230 are employed in the NE polder and 210 in Delft. In terms of area of land, there are two acres approximately in the original hydraulics buildings in Delft, approximately 40 acres in the new compound at the Delft Technical Institute, and 300 acres at the Laboratory De Voorst.

HYDRAULICS LABORATORY, UNIVERSITY OF LONDON

18. On 23 April I visited the hydraulics laboratory facilities of Imperial College, University of London, in London. During this tour I was escorted by Mr. Morris Kenn, Senior Lecturer, Hydraulics Department. Professor J.R.D. Francis, Head, Hydraulics Department, was not present. The hydraulics laboratory occupied approximately 10,000 sq ft of floor space within the College building. Among the types of studies in process were: one study of the resistance of a rock tunnel using prototype data obtained on a tunnel in Malaya; flow with wave action superimposed on a sand bed model; study of movement of sediments such as rocks and sand grains in a flume; a coriolis table approximately 25 ft in diameter which was under construction. Mr. Kenn considered coriolis forces to be important in the Northern Hemisphere since they cause 5-mph currents in the English Channel. Most of the small studies by Master Degree students were being conducted in small 4-in.-wide flumes, approximately 12 ft long. An improvised wave model was constructed using a tarpaulin lapped over concrete blocks outlining the rectangle for the harbor plus a wave machine to generate the waves. Another study had to do with cavitation caused by air entrainment. This study was related to the cooling water system for a nuclear submarine. A model of a dam spillway was under construction for study of the design. A hydrology study included a series of pipes with shower heads to sprinkle water or "rain" onto soil. The water then flowed through the soil to provide information on time of concentration and permeability factors.

HYDRAULICS RESEARCH STATION, WALLINGFORD, ENGLAND

19. On 24 April I visited the Hydraulics Research Station of the Ministry of Technology in Wallingford, England (Appendix F). To reach Wallingford, I took an hour train trip from Paddington Station, London, to Reading. At Reading I was met by a representative of the Hydraulics Research Station and driven to the Station. The Hydraulics Research Station has two main functions: (a) to investigate specific problems in the field of civil engineering hydraulics for organizations both in the United Kingdom and overseas; and (b) to conduct research in support of this work. The topics covered include flow associated with hydroelectric structures and with weirs, spillways, and other control works; flood relief; the training and control of rivers and estuaries; the development of ports and harbors; and coast erosion. Scale models are used extensively. The total budget of the Station is approximately one million pounds a year, or $2,400,000. The research efforts, which account for approximately one-third of the total program of the Station, are financed by Federal funds from the Ministry of Technology. The remaining work, approximately two-thirds of the total budget, is reimbursable type studies done for other elements of the National Government and for private firms and foreign governments.

20. At Wallingford I met Mr. R.C.H. Russell, Director of the Station. He had visited the Waterways Experiment Station in Vicksburg approximately ten years ago. Among other things, we discussed techniques for containing oil spills and the possible use of floating booms. It was Mr. Russell's opinion that the booms could not be held together in waves of any magnitude. The Station at Wallingford works quite closely, according to Mr. Russell, with the Delft Laboratory. Just recently they had an exchange of instrumentation personnel for a visit of approximately one week. The Station at Wallingford occupies an area of approximately 90 acres and has a staff of 250. As with Delft, this staff included personnel to obtain prototype data.

21. For my detailed tour of the Station, I was turned over to Mr. Jaffrey, who had visited Vicksburg less than a year ago. Mr. Jaffrey, a Section Chief, was to act as my guide. As noted by Mr. Fortson in his visit in 1963, the bulk of the models at Wallingford are housed in one large main hall. The hall has overhead cranes to aid in moving equipment and in taking photographs. The general appearance of the hall was that the maximum utilization had been made of the available space; in fact, the models appeared somewhat crowded. The general appearance of the equipment and of the model construction was that it was not nearly as lavish as that of the Dutch at Delft. In fact, in the model construction, the roughness elements seemed to be more of an improvised or expedient material and techniques, such as individual stones or pebbles lying on the concrete, and folded metal mesh loosely placed on top of fixed-bed models. The importance of doing a study quickly was emphasized on several occasions by the English engineers who would say that they had to get the results of their study to the contractor who wanted to start construction or to proceed with construction. The impression given me was that in some cases the results might have been given to the contractor sooner than the engineers would have liked.

22. As at Delft, the instrumentation of the Wallingford Station was quite handsome. There appeared to be more use of mechanical, gear-type equipment rather than electronic equipment for programming tides and waves. The collection of data was similar to that at Delft in that it was by electrical instruments that sent signals to digital recording machines capable of carrying up to 100 channels and reading each channel up to ten times a second. These readings were printed on paper tape for later use. Much greater use was made of pneumatic devices for tidal and wave generation than I had seen at other laboratories. In addition to spilling weirs for tidal generators, pneumatic tide generators were used, whereby water was sucked into large boxes and then released in a programmed manner. Only one model, a wave model combined with a

tidal effects, used a valve generator comparable to that used at Vicksburg. Mr. H.R.A. Dedow, Chief of the Instrumentation Branch, explained that they had little confidence in the valve technique and much preferred the spilling weir or pneumatic tide generator.

23. For movable-bed studies, many different types of material were being used, such as sand, granular plastic, granular coal, clinkers, and treated sawdust. Mr. Jaffrey indicated that they were obtaining good results with all of these materials.

24. Although the Station had done some model work outdoors in the past, the trend was toward having all models operated under shelters. Several larger sized models were being constructed and operated at some distance from Wallingford. One is a model of the Humber estuary, another is a large model of the Thames estuary. The Hydraulics Research Station at Wallingford has supervision of the technical operation of these models away from their home station. In none of the models at Wallingford were attempts made to reproduce coriolis effects.

25. Little mathematical modeling was under way or under consideration. A computer had only recently been installed at Wallingford. Part of the time they had used a computer at a nearby atomic energy authority installation. At the present time the computer is used largely for calculations and data processing. They are beginning to move slowly into the use of mathematical models for refraction of waves and flood routing.

The writer, who was director of the WES in 1969, visited three

CONCLUSION

(concluded that there are)

26. After visiting these foreign laboratories and discussing the visits with our own engineers at Vicksburg, I have come to the conclusion that we all have very many common programs and problems. There are more similarities about our model scales and techniques than there are differences. The differences, where they occur, are mostly due to differences in the problems being studied. I found my trip to be well worth the time and effort, and feel that senior engineers of the Waterways Experiment Station should make periodic exchange visits to foreign laboratories in the future.

DELFT HYDRAULICS LABORATORY
RAAM 61 DELFT NETHERLANDS

The Delft Hydraulics Laboratory is pre-eminently an institute for hydraulic research. The field of activity comprises applied research, fundamental research, hydrodynamics and instrumentation development.

The LABORATORY acts as consultant for designs requiring special hydraulic knowledge and experience. Calculations, studies with small-scale models, site investigations and knowhow are the supports in this consultative work. It carries out assignments for public authorities and private organizations in the Netherlands and abroad. The direct cost of the studies, increased with a proportional share in the general cost, is charged.

Organization.

The DELFT HYDRAULICS LABORATORY was established in 1927 and forms, together with the Delft Soil Mechanics Laboratory, the "Stichting Waterbouwkundig Laboratorium" (Foundation Hydraulic Engineering Laboratory), an independent non-profit organization, which is controlled by a Board consisting of representatives from the government, scientific institutions, engineering consultants and contractors appointed by the government of the Netherlands.

THE DELFT HYDRAULICS LABORATORY covers the LABORATORY DELFT, the LABORATORY DE VOORST and the SITE INVESTIGATION SERVICE.
Apart from the specialized branches in the various fields of hydraulics or hydrodynamics belonging to both laboratories, the organization includes a Mathematics and Instrumentation Branch and a Documentation Service.

The various specialized branches cover the following subjects:

hydrodynamics and morphology	rivers
density currents	weirs, sluices and locks
coasts and estuaries	navigation
harbours and waterways	pumps and industrial circuits
maritime structures	

For problems demanding additional scientific background beyond the scope of the own specialization, the LABORATORY maintains close contacts or co-operates with various institutes, such as the Organization of Applied Scientific Research T.N.O., the Royal Netherlands Meteorological Institute, the Ship Model Basin at Wageningen, governmental services and universities. Site investigations are often set up as part of a more comprehensive survey organized by engineering consultants.

APPENDIX A

DELFT HYDRAULICS LABORATORY
RAAM 61 DELFT NETHERLANDS

ORGANIZATION 1 November 1968

DELFT HYDRAULICS LABORATORY

H. J. Schoemaker, director   J. E. Prins, deputy director

COORDINATION BASIC RESEARCH

dr. M. de Vries   dr. G. Abraham

CENTRAL OFFICES

Accountancy	C. J. Kuyvenhoven
Public Relations	L. R. de Vlugt
Library and Documentation	J. R. Thierry
Instrumentation	J. van der Wel

ADVISORY BRANCHES

Density Currents	dr. G. Abraham
Maritime Structures	K. d'Angremond
Pumps and Industrial Circulation	J. Wijdieks
Tidal Model Rijnmond	G. van Riessen
Sediment Transportation	H. N. C. Breusers
Weirs and Sluices	P. A. Kolkman

LABORATORY DELFT

A. Paape, head

Technical services	J. P. M. Commandeur
Mathematics	A. C. M. van Ette

Branch I	H. de Groot
Branch II	D. Gersie
Survey teams abroad	

SITE INVESTIGATIONS SERVICE

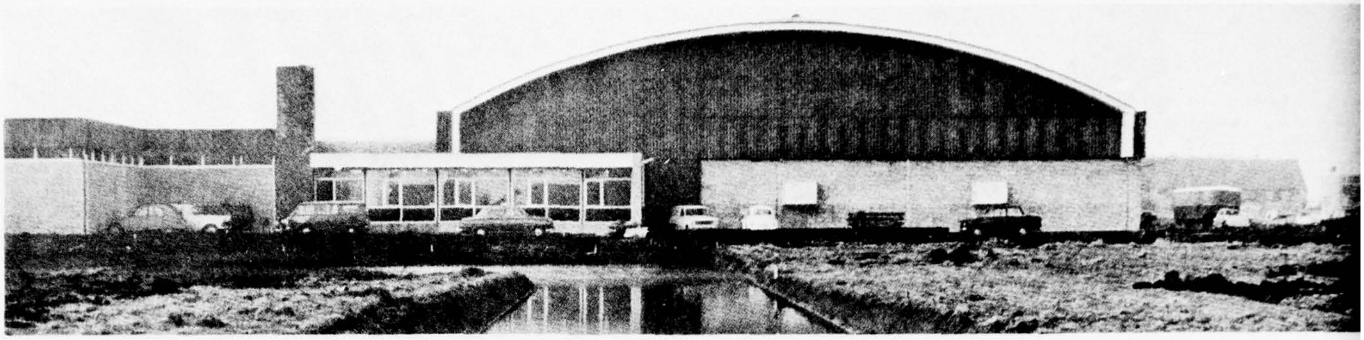
J. G. H. R. Diephuis, head

Enclosure Works	T. van der Meulen
Harbours and Coasts	R. Reinalda
Hydrodynamics and Morphology	E. Allersma
Maritime Structures	J. van der Weide
Rivers and Navigation	D. Gersie

Mathematics	C. B. Vreugdenhil
Technical services	M. Reinalda

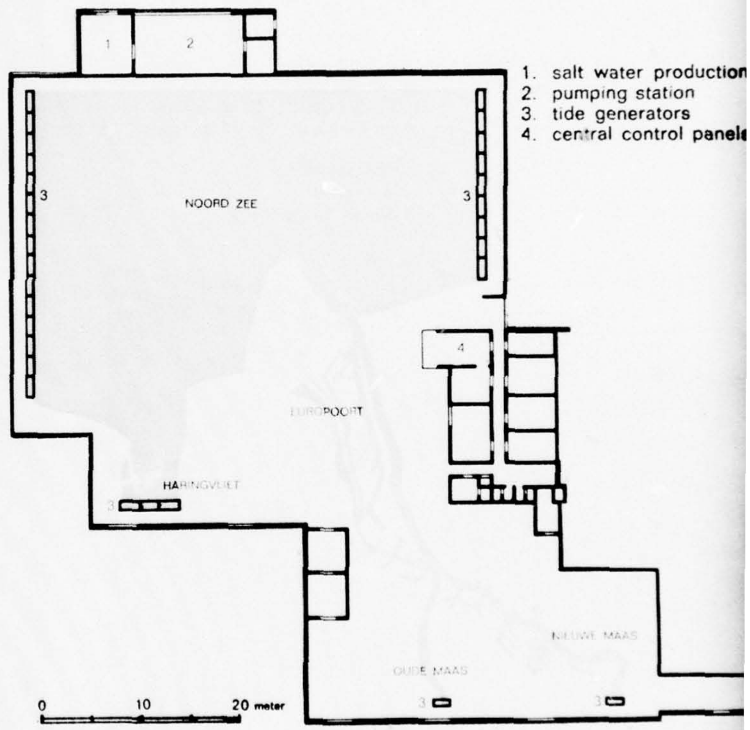
LABORATORY DE VOORST

J. J. Vinjé, head   D. Gersie, deputy head



Rotterdam, now acknowledged to be the largest port in the world, must in the interest of the Netherlands remain so in the future. But to ensure this, a great deal has to be done.
There must be ample space, for example, for ocean-going vessels with their ever-increasing tonnage and greater draught. This space has already been provided for in Europoort, but the opening up of the full area necessitates a new connection with the New Waterway and the construction of harbour dams out into the North Sea. For only when that is done will it be possible to pilot in the mammoth ships, even the largest to be constructed, at all phases of the tide.
To determine in detail the size and form of the new harbour dams and to decide on the right shape of the definite entrance into the Europoort harbours, the Bouwbureau Havenmond Hoek van Holland (Construction Bureau of the Rhine Mouth at the Hook of Holland) of the Government Waterways Department ordered the building of a working model through which both salt and fresh water could stream under careful control. In short, it should be possible to study in detail the nature of the changing currents in the New Waterway and outside the harbour by reproducing the North Sea tides under varying conditions.
This model research will then supply the information necessary for designing the shape of the harbour entrance as well as deciding the construction phases for the harbour dams which will stretch out into the sea. The main criterium throughout the study will be ensuring the maximum coditions to guarantee safe navigation of the largest vessels under all circumstances.

The Rijnmond tidal model



1. salt water production
2. pumping station
3. tide generators
4. central control panel

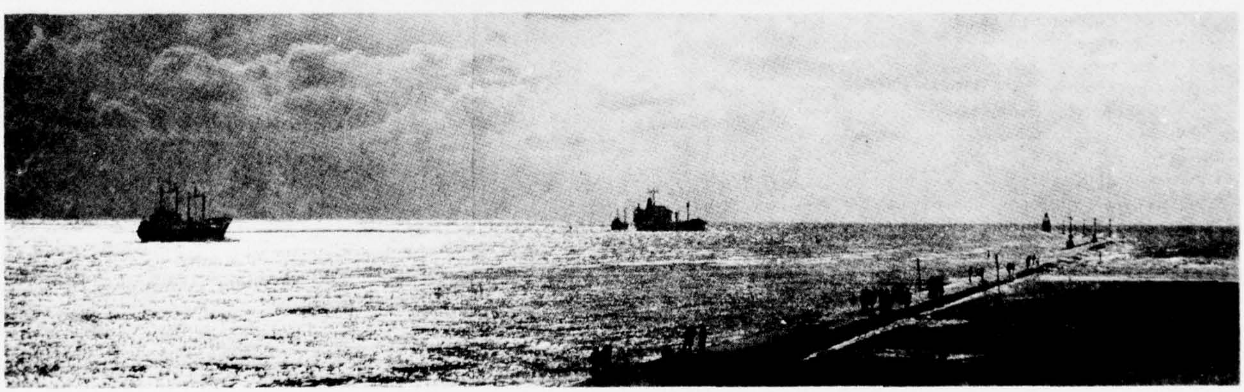
Scales: Horizontal 1 : 640; Vertical 1 : 64
Watercirculation: 1.5 m³/sec
Salt consumption per test: 5 to 10 tons

2

Delft Hydraulics
Laboratory.
Link between
Science and Practice

- **Delft Laboratory**
- **De Voorst Laboratory**
- **Site Investigations Service**

In the course of years the great expansion in the growth of the Delft Hydraulics Laboratory has kept pace with the need for specialised research in the field of hydraulics, so that now it can offer a wide range of knowledge to all connected with national and international hydraulic works and problems.
This growth, however, is an understandable result of the technical and economic development of the past few decades, much of it stemming from modern advances in transport facilities, energy production, the food position, and the living conditions of a country.
These factors, it should be realised, are to a considerable extent linked with civil engineering works the effectiveness of which, as well as their operational certainty and guarantee of safety, are determined by hydraulic considerations. Many of these factors cannot be provided, however, without laboratory research.
Moreover, advice of an hydraulic character is usually of direct economic interest, as it leads to important savings in construction costs or exploitation expenses.
In 1962 an extensive study was performed by the Delft Hydraulics Laboratory to determine the nature and the size of advisory work to be expected in this field of hydraulics. This study took into consideration especially the undeniable tendency to make increasing use of scientifically justified and effective services of specialised institutions in the preparation of projects.
This naturally was largely associated with the large hydraulic works being carried out and planned by the Netherlands Ministry of Waterways, as research on this type of project had been developing since the Laboratory was established in 1927. But in recent years this development revaled a sort of explosive character in the form of advisory work for the lower public authorities, engineering consultants, and industry and trade, while an increasing proportion of the activities comprised the preparation of projects for foreign countries.
On the basis of the forecast produced by the studie into the development of this type of research, and to supplement the activities of the Laboratory De Voorst, a programme of new buildings for Delft has been drawn up. In addition to accommodation for the central services, the new complex will house the Site Investigation Service, the theoretical sections of hydrodynamics, computor programming and data processing, and the Instrumentation Department, as well as giving space for model investigations to be carried out by the Branches covering Density Currents, Maritime structures, Pumps and Industrial Circuits, and Weirs and Locks.
The new building will be located on the outskirts of the Technical University complex in the Zuidpolder at Delft in the area which already accommodates the Rijnmond tidal model and in which work has started on the building of the new wind wave tunnels.
These new facilities which are being added at the moment will, in the future, ensure the task which the Delft Hydraulics Laboratory fulfils as intermediary in the afore-metioned technical and economic development.



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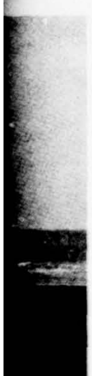

APPENDIX B

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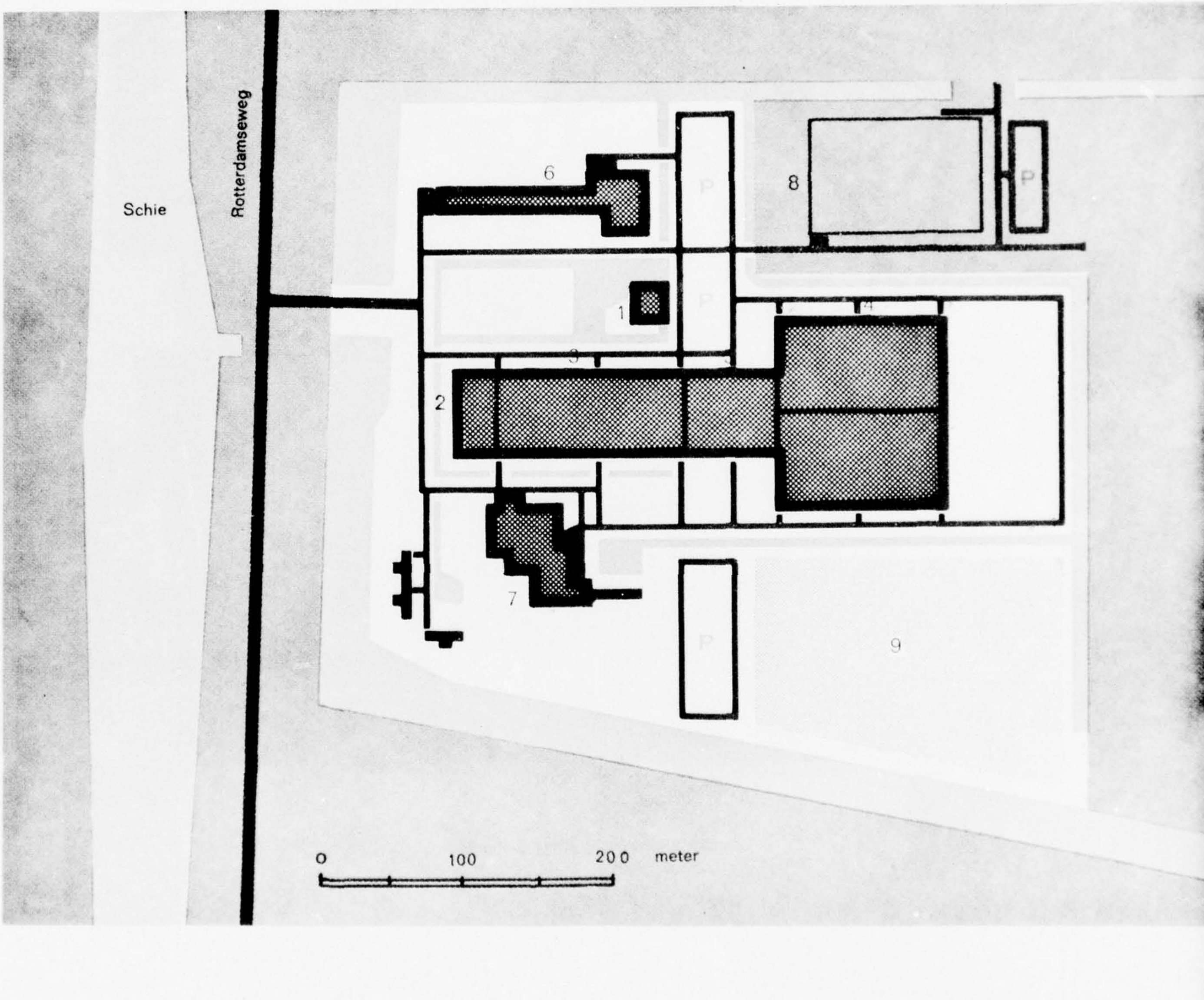
The Delft Hydraulics Laboratory is building a new complex in the Zuidpolder near Delft.
This will ensure that the Netherlands will continue in the future to maintain its leading position in the field of hydraulics.

1. main office building
2. laboratory for pumps and industrial circuits
3. halls for model investigations
4. models with salt and fresh water
5. workshops and instrumentation laboratory
6. wind tunnels building
7. Rijnmond tidal model
8. ship-manouvring basin of the Technical University
9. reservation for temporary sheds



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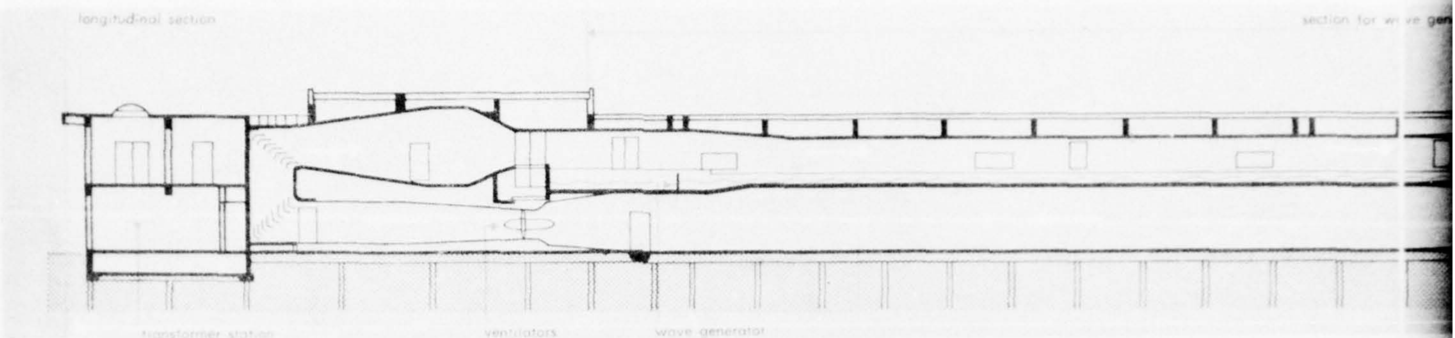
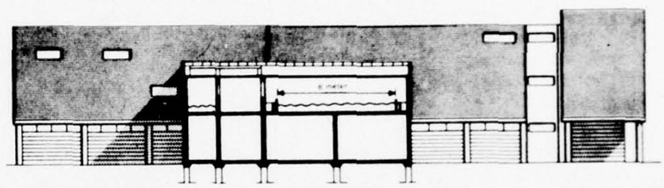


Wind tunnels building



During the past few years a considerably deeper insight has been obtained into the generation of wind waves. Especially has the development of the instrumentation and control techniques made available better means for observation and characterization of waves under natural conditions and for reproducing them in a wind-wave tunnel.
This new development has provided the basis for two new wind-wave tunnels which will in the future serve as additional aids for the increasing intensity of the model studies for maritime constructions.
In modern research connected with the designing of water-control works, breakwaters and drilling platforms, the models are exposed to such a variety of simulated natural conditions that the designer can give his proposed construction the optimum dimensions. At the same time, all risks can be carefully evaluated as to their importance for maintenance, choice of material and the safety of those building or operating the structures.
The extensive knowledge and experience the Delft Hydraulics Laboratory has gained in this field date back to 1938, when it first started the study of models in a tunnel with waves generated by wind. In 1956 a second and larger wind-wave tunnel was taken into use in the De Voorst Laboratory. Until lately, indeed, both tunnels were unique in the world of hydraulics.
The two new wind tunnels along with a few flumes for tests with regular waves are now being housed in a new complex. In designing those facilities, special attention was paid to the size and technical provisions of the installation which are greatly determined by the character of the wave motion in nature. This complex phenomenon can only be described satisfactorily with the aid of statistical quantities, so the reproduction of the wave motion is tuned to this by means of wave generators whose movements are determined by a programme containing the necessary statistical characteristics. The adaptation of the details of the shape of the waves is obtained by an air stream running over the full 100-metre length of the tunnel.
Special provisions have also been made for study of such problems as the relevant effects of the wave movements in combination with currents from different directions.

Basis for security and effectiveness

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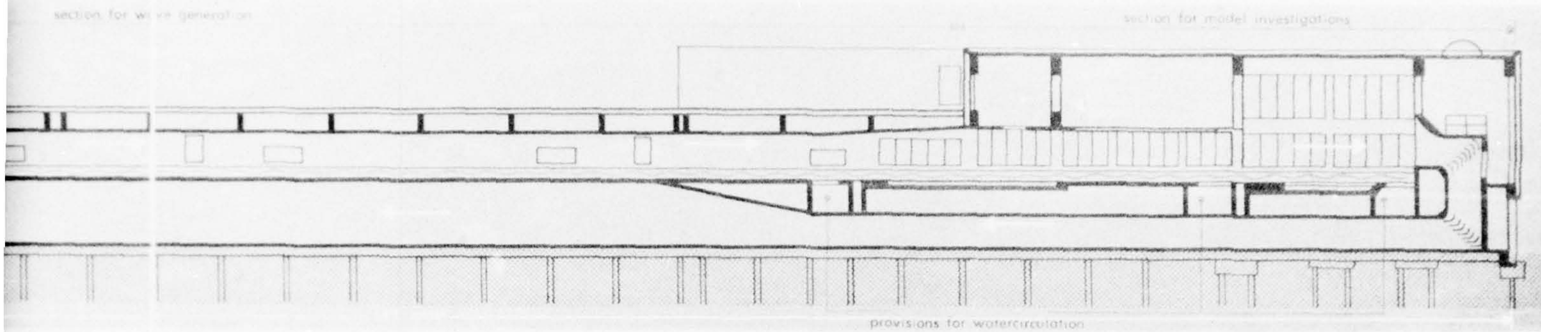

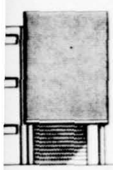

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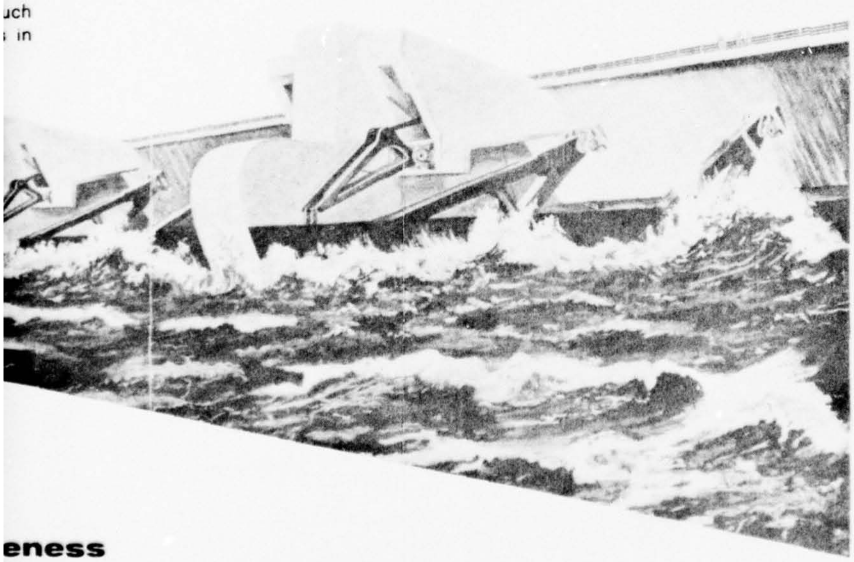
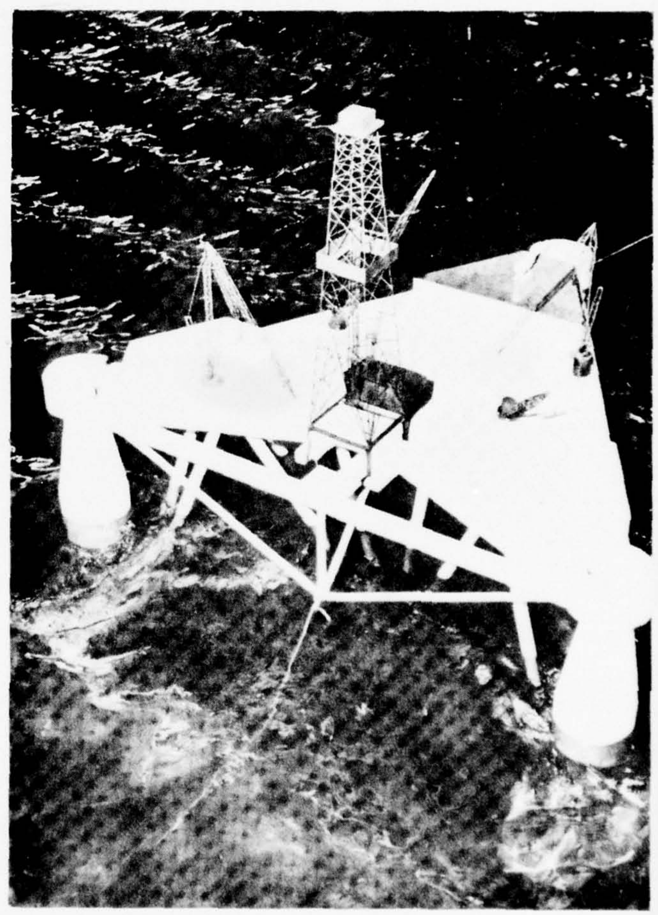
Main Features of the Wind-wave Tunnels:

	Large Tunnel	Small Tunnel
Length:	100 metres	100 metres
Width at water-line:	8 metres	2 metres
Width in wind profile:	9.5 metres	2 metres
Height:	2.45 metres	2.45 metres
Maximum water depth:	0.8 metres	0.8 metres
Ventilators:	4 x 60 kW	1 x 60kW
Wind speed:	0 - 15 m/sec	0 - 15 m/sec
Water circulation of pumps:	4 x 0.2 m^3/sec	4 x 0.2 m^3/sec

Architect: Bureau op ten Noort-Blijdenstein
Installation Advisor: Bureau P. W. Deerns
Main contractor: Internationale Bouw Compagnie.





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NEW WIND-WAVE FLUMES AT DELFT

published by the 'Associatie van
Ingenieurs en Architekten Buro
op ten Noort-Blijdenstein' (Consulting
Engineers), Utrecht, The Netherlands

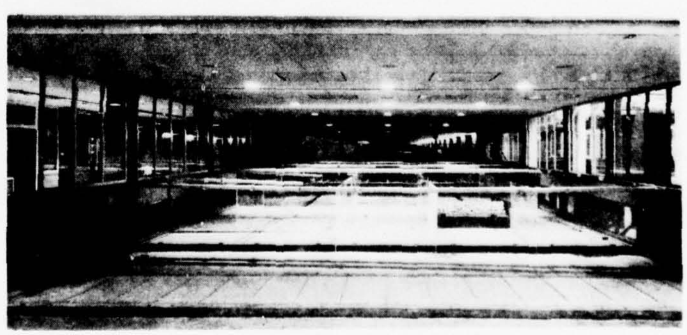
APPENDIX C

INTRODUCTION

1 **Building of the wind-wave flumes at Delft**

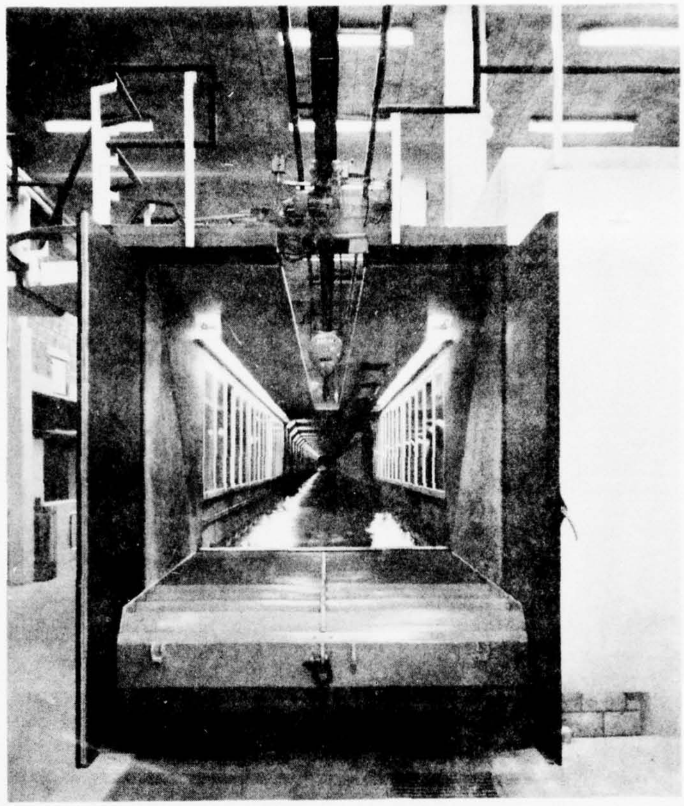
The optimal design of maritime structures is possible if reliable data are available with regard to their behaviour under the influence of currents, wind and waves.
These data have to be obtained from model studies in a wind-wave flume.
The insight into the generation of wind-waves, and the knowlegde about wave attack on structures, has deepened to such an extent in recent years that the equipment used upto now in these model studies can no longer be considered as adequate.

Consequently at Delft the need was felt for the construction of a new wind-wave flumes building to generate wind-waves and to reproduce waves in combination with currents, so that model studies



2 **Inside of the large flume as seen from the wave-basin**

could be carried out according to modern conceptions, employing the most recently-developed control equipment and technical installations.
The design work for the building started in 1964, the contract for the construction was awarded in February 1967 and the building with installations was completed in November 1968.
The official opening bij the Director-General of the 'Rijkswaterstaat' (Government Waterways Department) will take place on March 24, 1969.



3 Small flume with vanes in front

MAIN DESIGN FEATURES

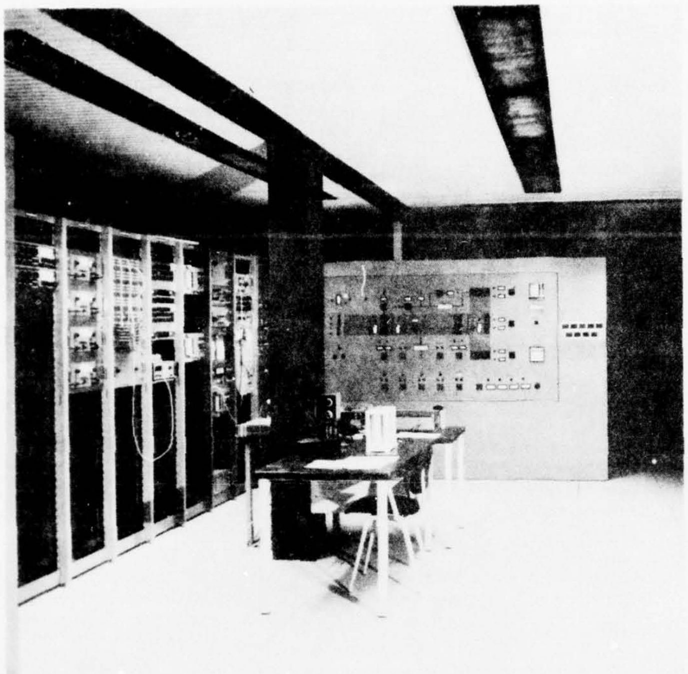
From the outset the building was designed as one organic entity constructed mainly in reinforced concrete. It consists of:

a
The large wind-wave flume, including the model section, about 100 m long, 8 m wide measured on the water line and 10 m wide on the air profile.
It is connected with a wave basin of 10 x 25 m^2. The flume can be divided into 3 sections by means of baffles.

The small wind-wave flume, about 100 m long including the model section, 2 m wide measured on the water and air profiles divisible into 2 sections by means of baffles.

In these flumes and in the wave basin it is possible to generate:
- wind and wind-waves (air circulation),
- waves generated by a programmed wave machine,
- water flow in 2 directions (water circulation), and
- combinations of the various possibilities.

4 Hall for construction of models



b
Observation windows in the walls of the flumes, above and below the water level, with recessed walkway adjacent to the large flume.

c
Air ducts with aerodynamically-shaped stilling chambers.

d
Separated construction and control sectors for the models, enabling a high degree of occupancy by exchange of models.

e
Transport facilities for the construction and exchange of models, equipment and materials.

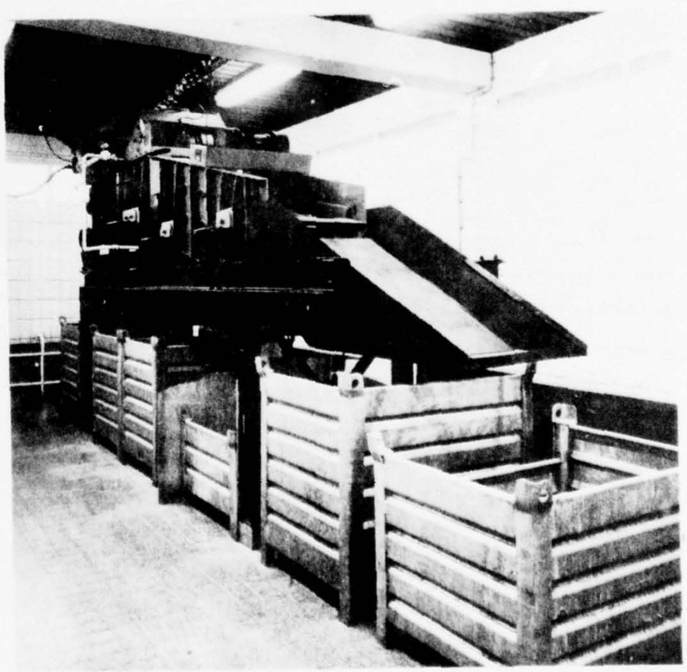
f
Movable ceiling of model section in the large flume so that the general service crane in the building can also be easily used in the construction hall and in this model section.

5 Control room for large flume

g
Conditioned control room for each flume to accommodate fixed and movable control and recording equipment.

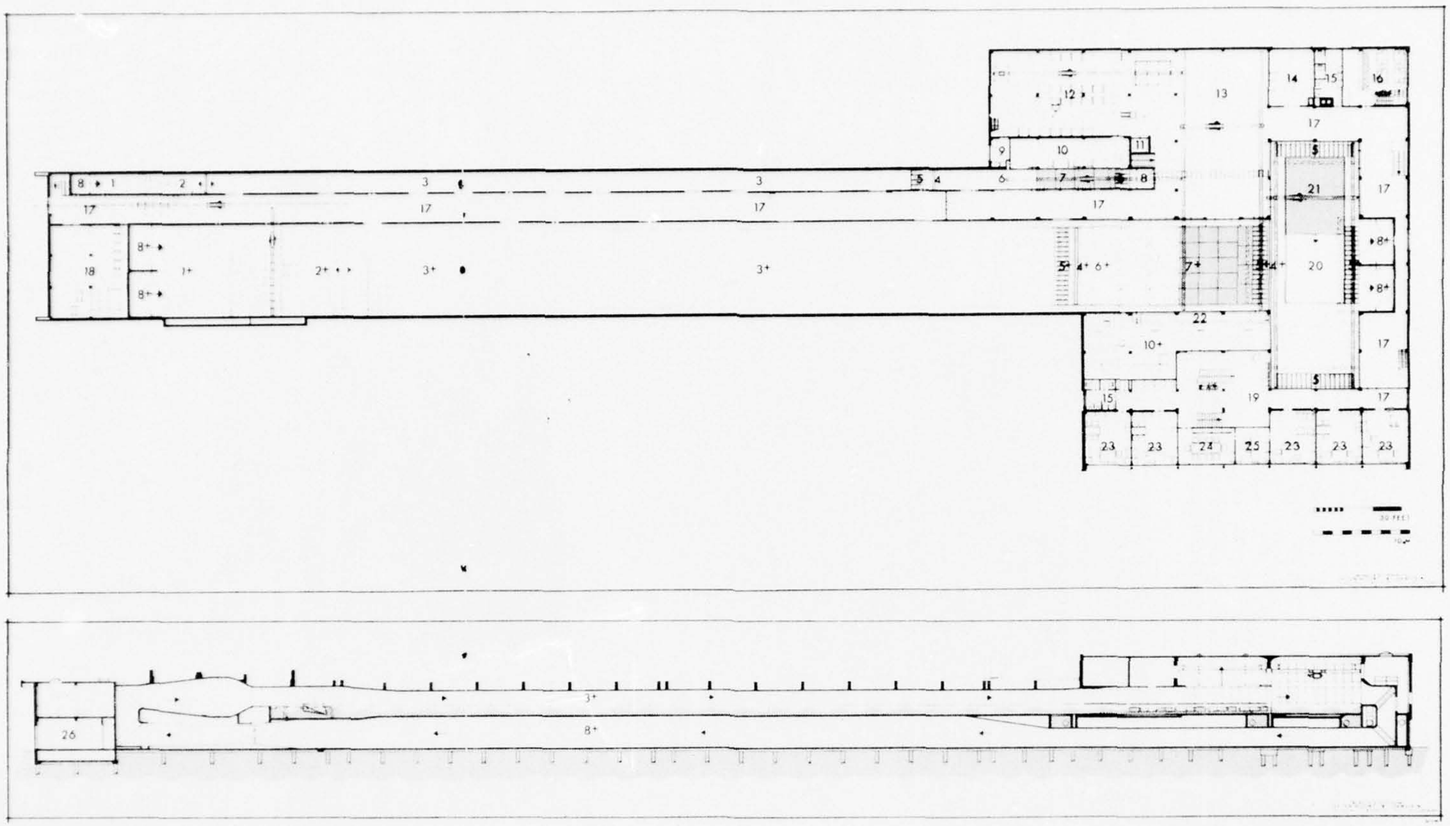
h
Offices for staff, administration and mathematics division.

i
Additional utility spaces, such as pumping-room, space for heating and air-compressor installations, sieving installations, model materials, etc.



6 Sieving installation

WIND-WAVE FLUMES



Reference

1- 1+	Stilling chamber	10-10+	Control room	18	Engine room
2- 2+	Wave-generator	11	Elevator	19	Entrance hall
3- 3+	Wave-generation section	12	Storage	20	Wave-basin
4- 4+	Movable barrier	13	Construction hall	21	Movable floor
5- 5+	Discharge channel	14	Workshop	22	Recessed walkway
6- 6+	'Adjustable sea-bed' section	15	Toilets	23	Offices
7- 7+	Model section	16	Canteen	24	Conference room
8- 8+	Return channel	17	Corridor	25	Reception room
9	Room for control of material densities			26	Transformator room

THE INSTALLATIONS

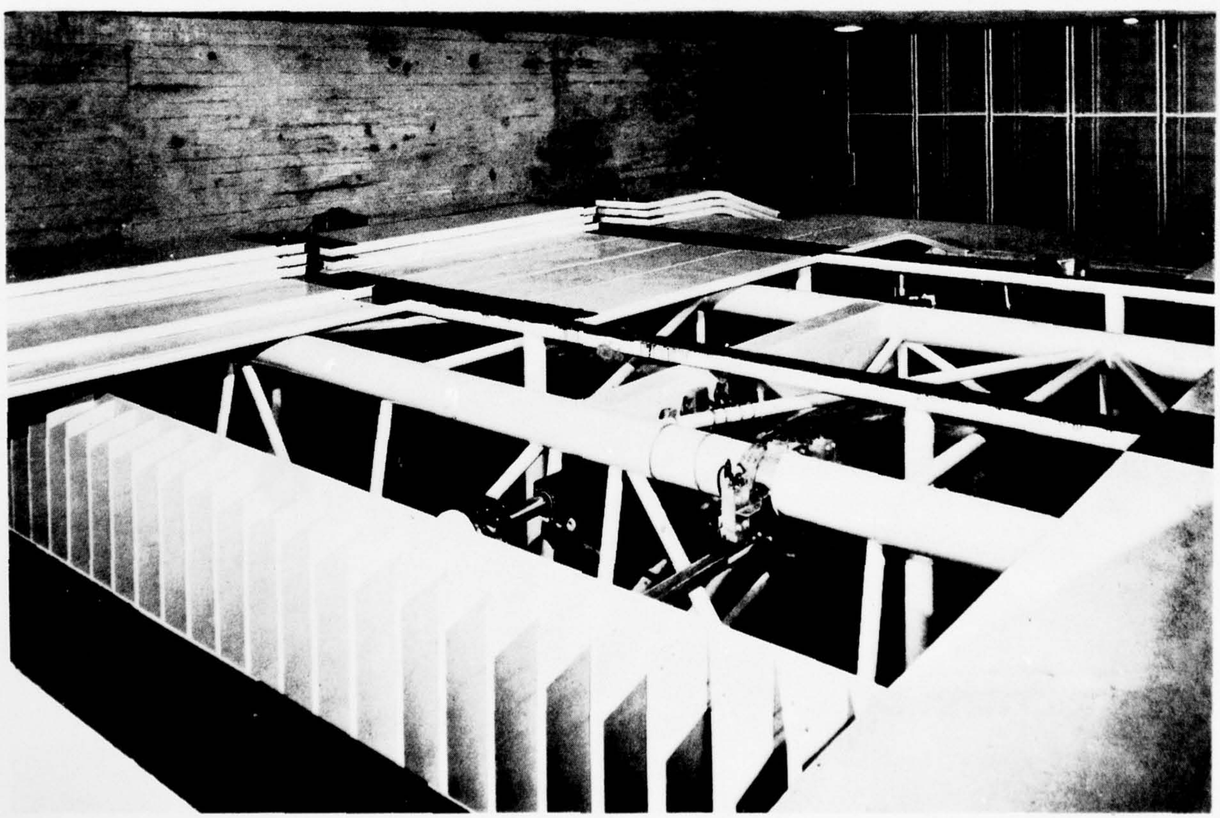
According to their specific functions, the installations used are distinguished as follows:

a The wind-generating installation
In the return channel under the large flume 4 axial ventilators have been installed, each with an impeller of 1.80 m diameter, able to supply 60 m^3 air per second at a static head of 50 mm water column, to attain a wind velocity of 15 m/s or 54 km/h. Placed outside the axis are direct current electric motors of 45 kW capacity with belt transmission reduced from 1 to 1.7. The number of evolutions per minute is continuously variable between 0 and 1,500; the tolerance amounts to ± 2%. The adjustment is made by means of transducers.
A similar ventilator, driven and controlled in the same way, is placed in the return channel under the small flume.
Particular attention has been paid to the distribution of the air flow over the water surface (the air profile is greater than the water profile), as well as to the design of the stilling chamber, deflection vanes, diffusers, etc.
The installation can be operated and controlled from the panels in both control rooms.

b The wave-generating installation
At the end of the flumes are programmable, servo-controlled, wave-generating machines which can be operated hydraulically.
By means of this installation, and by using punched or magnetic tape, natural wave records or a filtered random noise, it is possible to generate and maintain any desired irregular wave pattern with arbitrarily chosen energy spectrum.
The dimensions of the wave flaps are 8 x 1 m^2 and 2 x 1 m^2 respectively and they are suspended in a mobile carriage-structure. Each one is movable by means of 2 hydraulically-activated cylinders, one of which is attached to the carriage and the other inside the carriage at the top edge of each flap.
The carriage travels on the sides of the large flume and on rails along the walls of the small flume.
The power requirements of the oil pumps for the hydraulic movement amount to 68 kW and 23 kW respectively.
Operation, control signalling and automatic recording take place in both control rooms.

c The water circulation
In the large flume and in the wave basin a water flow can be maintained between any pair of two arbitrarily chosen channels from the total number of 5 in- and outflow channels. The maximum possible discharge amounts to 1 m^3/s corresponding to a maximum velocity of 0.25 m/s over the full width of 8 m at a water depth of 0.50 m.
In the small flume a velocity of 0.30 m/s with a water depth of 0.50 m can be maintained in a similar way between 2 channels. In the pumping room 5 water-lubricated centrifugal pumps have been installed for this purpose which have an output of 0.2 m^3/s at a lift of 8 m; two of these pumps can pump water into the small flume.
The in- and outflow channels have been so dimensioned that a uniform distribution of flow in the flumes is ensured.

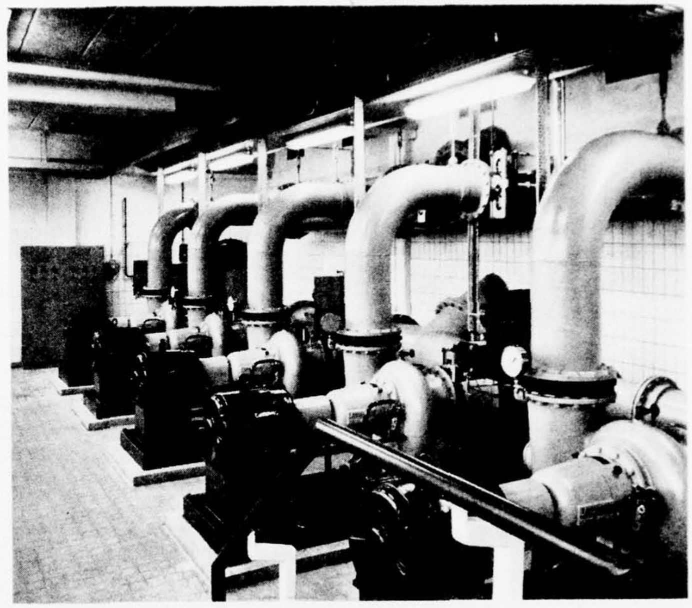
7 Wave-generation installation. In front the flap with hydraulic actuator at the top edge of the carriage; at the back the hydraulic actuator for moving the carriage.



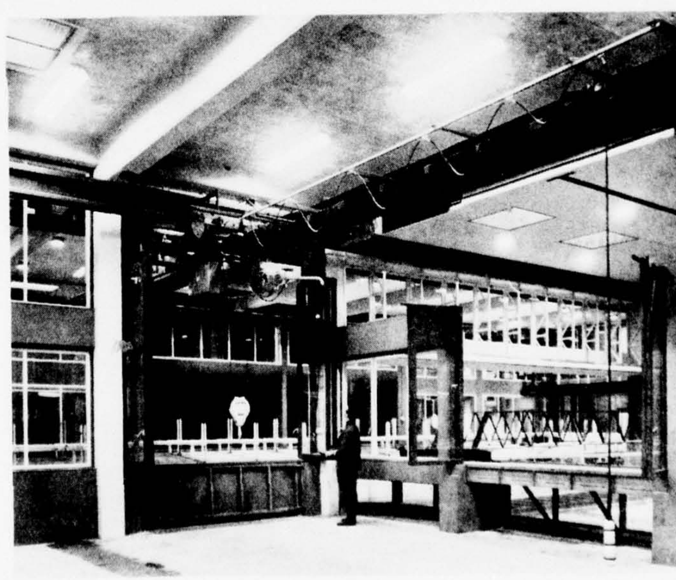
From the control room the water circulation can be remotely operated and controlled.
To prevent corrosion and the observations difficulties resulting therefrom, the entire installation has been coated in- and outside by nylon

d Auxiliary installations

To ensure smooth operation, fully adequate lighting and power plants have been installed. A feature of particular importance is the specially designed transportation and crane installation for transport of models, materials, and other necessities.



8 Pumping-room



9 General service crane providing transport facilities between the construction hall and the model section

SOME FURTHER DATA

The tolerances in the dimensioning of the flumes had to meet the following rigorous requirements:

— the floors + or — 1.5 mm relative to a horizontal plane and
— the walls + or — 2.5 mm relative to a vertical plane, so as to prevent distortion of the wave pattern as a result of irregularities in bed-level and walls.

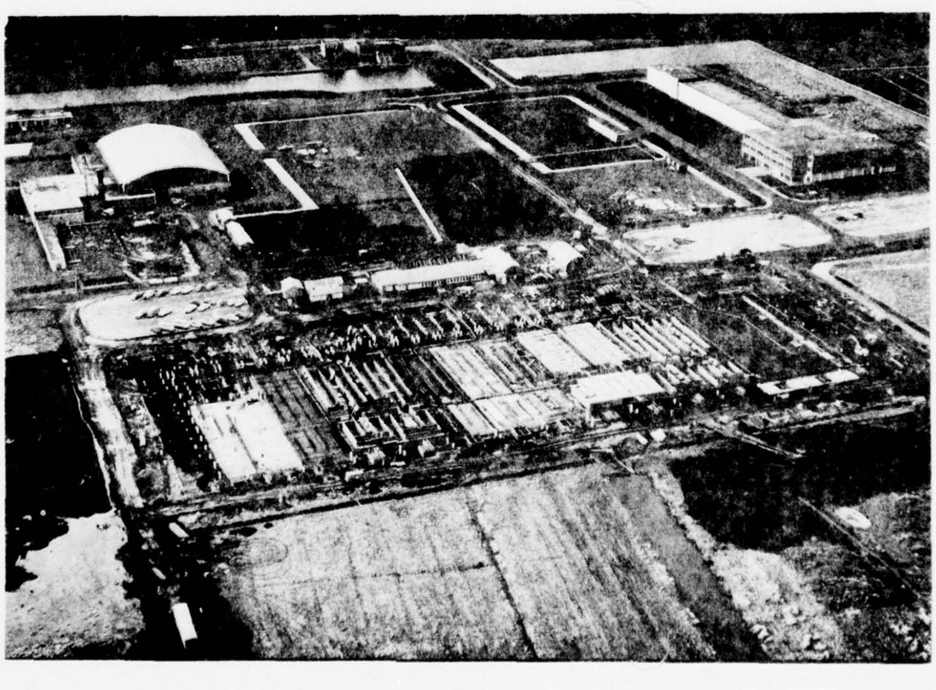
The *ceiling above the wave basin* is provided with heating elements to prevent condensation and the accompanying dripping of water into the measuring sections.
This is important in connection with a permanent high degree of humidity.

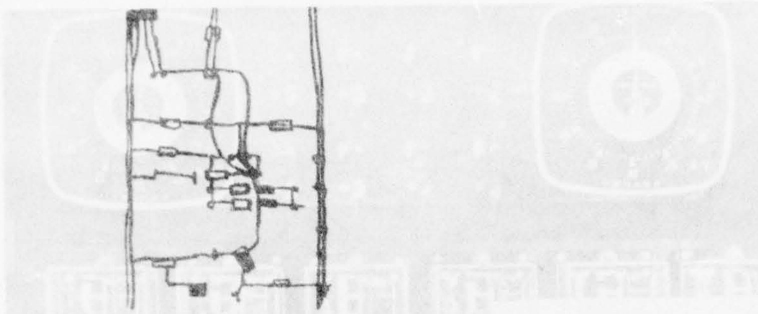
The building covers a area of 3.000 m^2 and has a total volume of 26.700 m^3.

Its cost (excluding purchase of land) *amount to* Dfl. 6.200.000 *of which* Dfl. 3.200.000 were for technical installations, corresponding to approximately Dfl. 2.000/m^2 built-up area Dfl. 230/m^3 building volume.

The layout was developed by the **Delft Hydraulics Laboratory** in co-operation with the '**Associatie van Ingenieurs en Architekten Buro op ten Noort-Blijdenstein**' (Consulting Engineers), Utrecht, The Netherlands. Its staff was responsible for the design and engineering of the plan and for the supervision and overall co-ordination of the construction.

10 **Aerial view of the new site of the Delft Hydraulics Laboratory (foto KLM Aerocarto NV)**





Development and construction of pick-ups, recorders and analysers for measurements in laboratories and on sites. Control.

Instrumentation

Fundamental research in the Laboratory is directec
complete and detailed efficiency in solving practical
using the theoretical and empirical approach. Both the
ena determinative for the problem and the means to c
them are involved: model technics, and measuring anc
methods. The Mathematics and Instrumentation Bra
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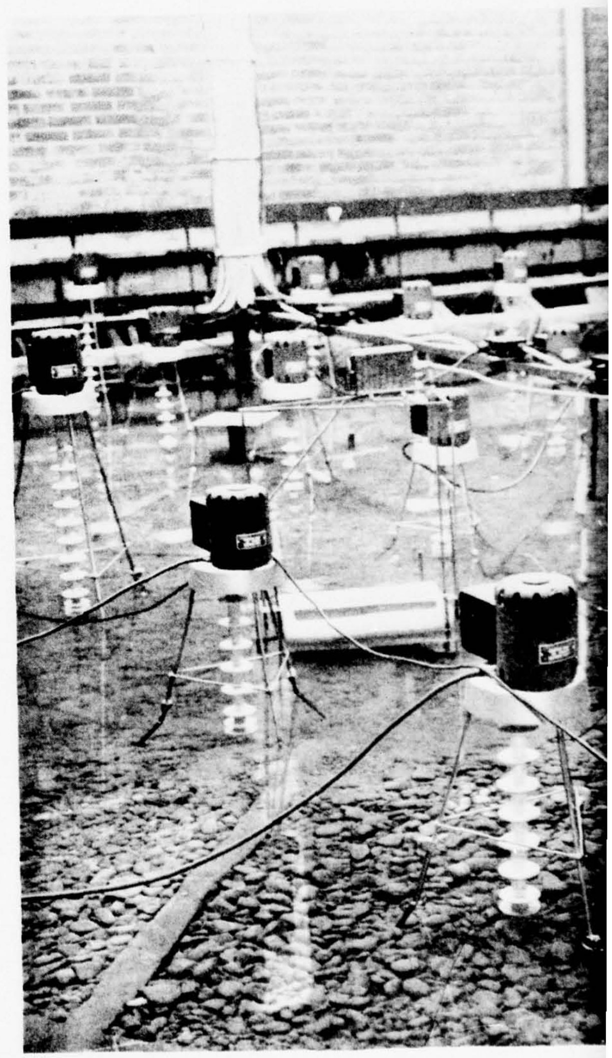
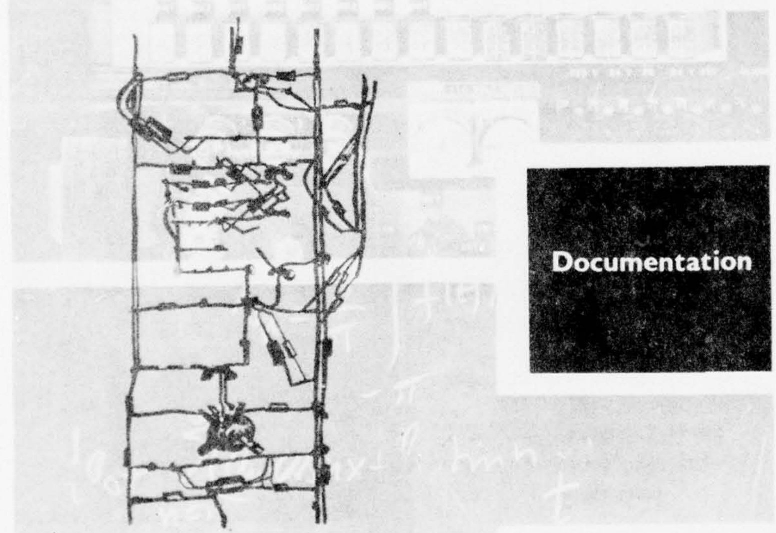
Service supplying matters of the cognate sciences also
the generation of original developments.

,,Coriolis-top'' to reproduce the rotation of the ear

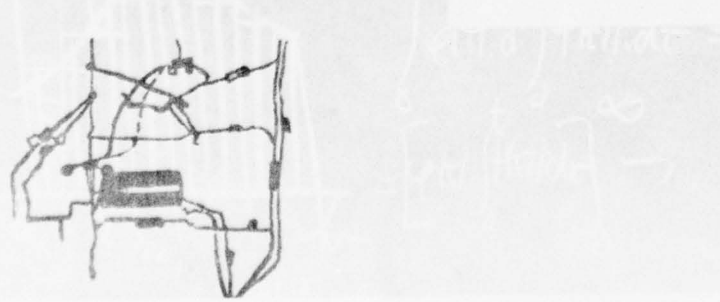




Documentation

Hydrodynamics. Development of computor programmes for hydraulic problems and data processing.

Mathematics



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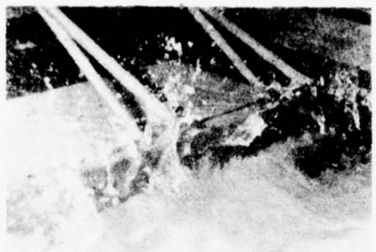
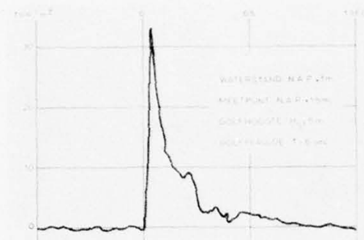
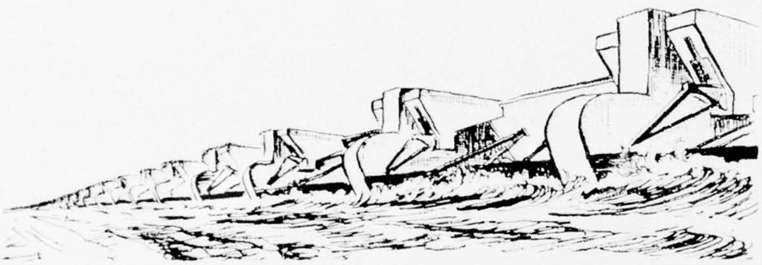
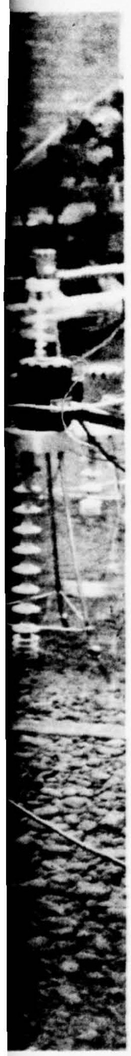


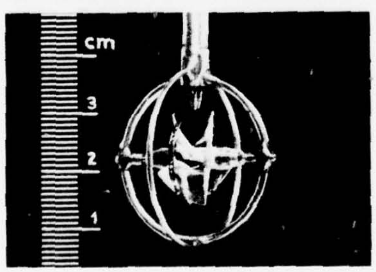
To reproduce the statistical characteristics of the natural waves, the Laboratory has two wind-wave tunnels. Model studies in these facilities enable the measure of risk to which the project is exposed to be determined. In this way the data obtained contain the elements required for an economically-justified project.

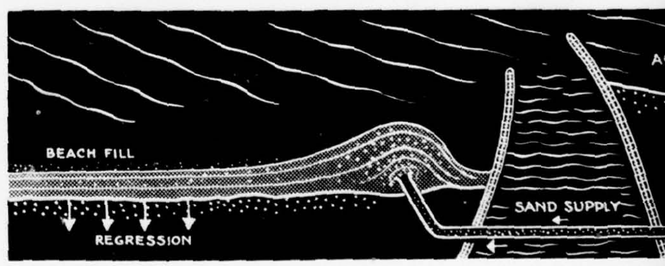


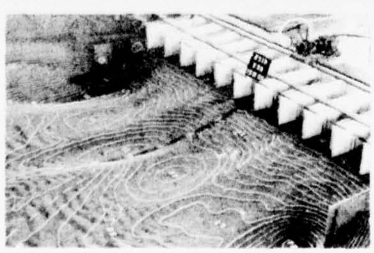




The properties of turbulence of flowing water play a very great part in determining the phenomenon of erosion of sandy beds and the vibration of weirs. An understanding of the scouring processes behind structures has been considerably extended by the development of instruments to measure and analyse turbulence. For the vibrations of weirs the application of elastically similar models has made it possible to reproduce dynamic similarity of the interaction between the structure and the water.







For the hydraulic engineer the model is just real as the project to be realized

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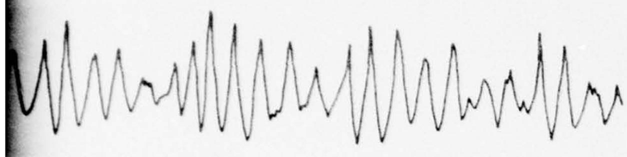

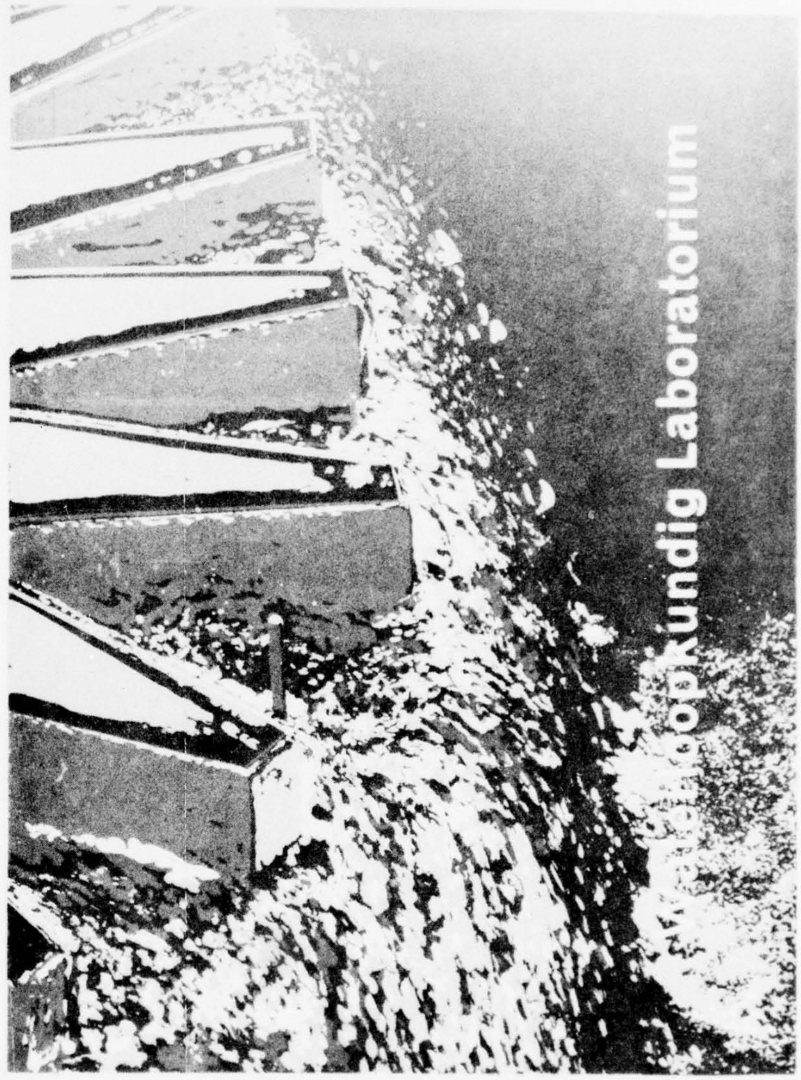

Delft Hydraulics Laboratory
Waterloopkundig Laboratorium
Laboratoire d'Hydraulique de Delft

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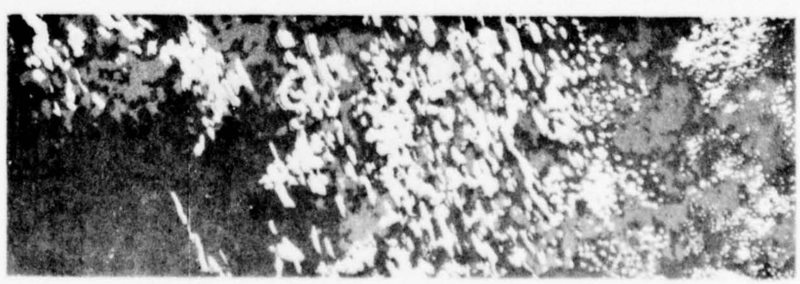

APPENDIX D

The Delft Hydraulics Laboratory

acts as consultant for designs requiring special hydraulic knowledge and experience

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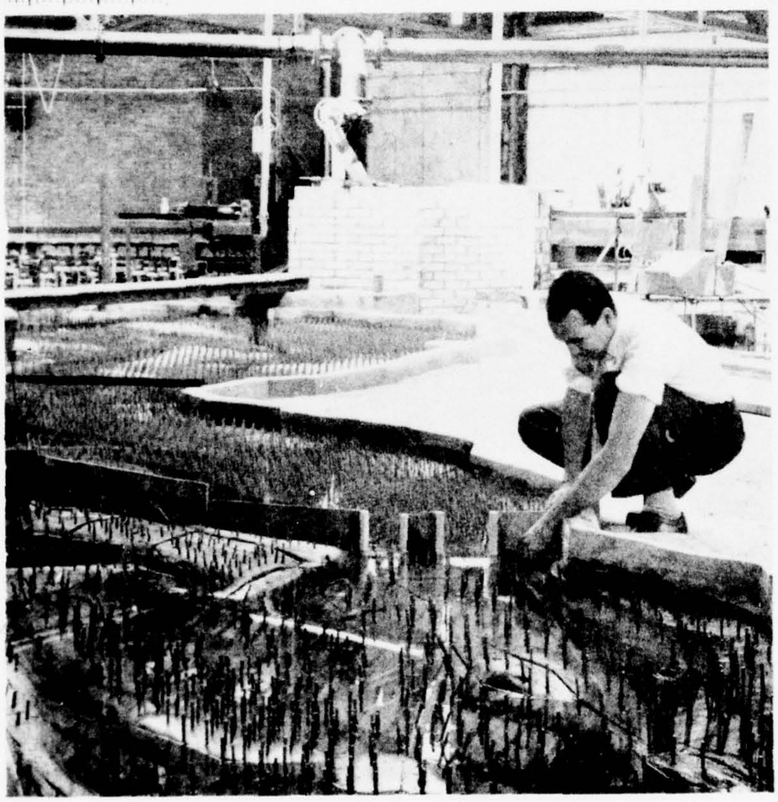
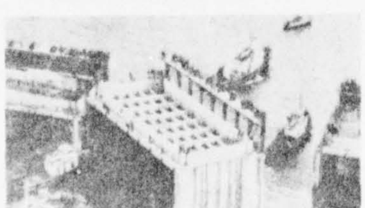


Investigations by models

Calculations

Site investigations



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was established in
nd forms part of the
ation „Waterbouw-
Laboratorium".

ies out assignments
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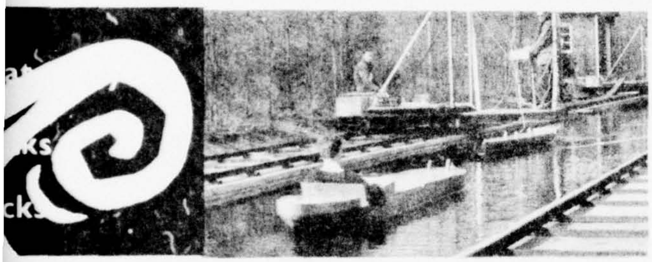
organizations in The
rlands and abroad.

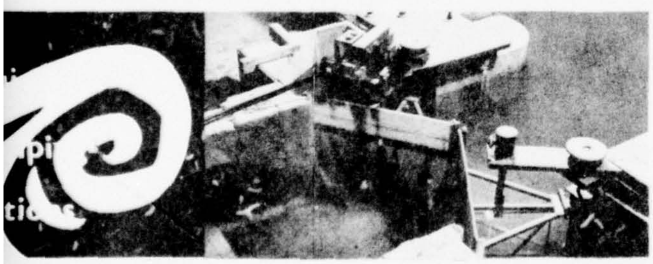
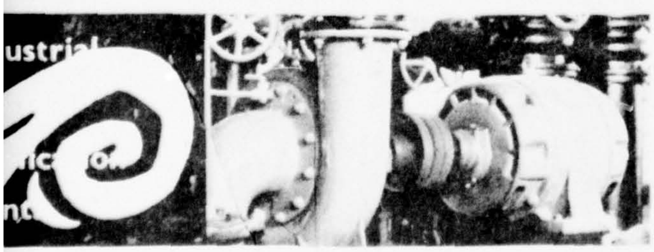
The main task of a practical hydraulics laboratory is the adaption of the achievements of science to the needs of engineering and building up a complete project by means of theoretical and experimental research as far as is required for a sound scientific background for engineering.

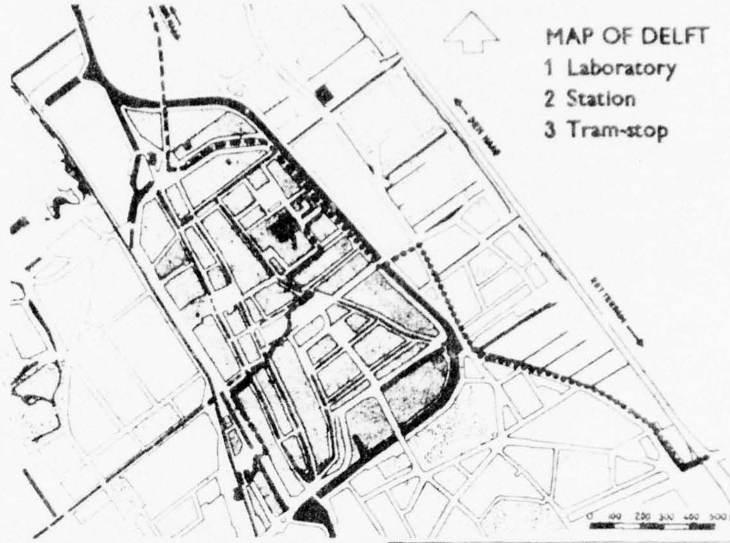
Link between science and practice

3





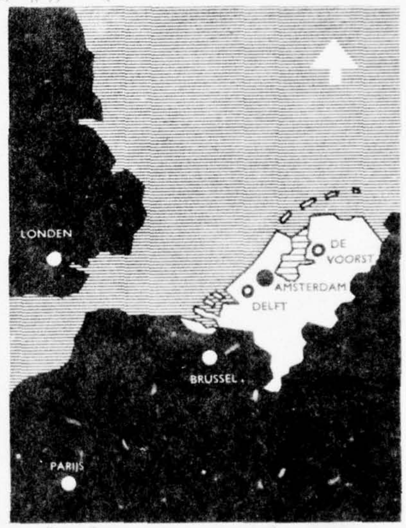


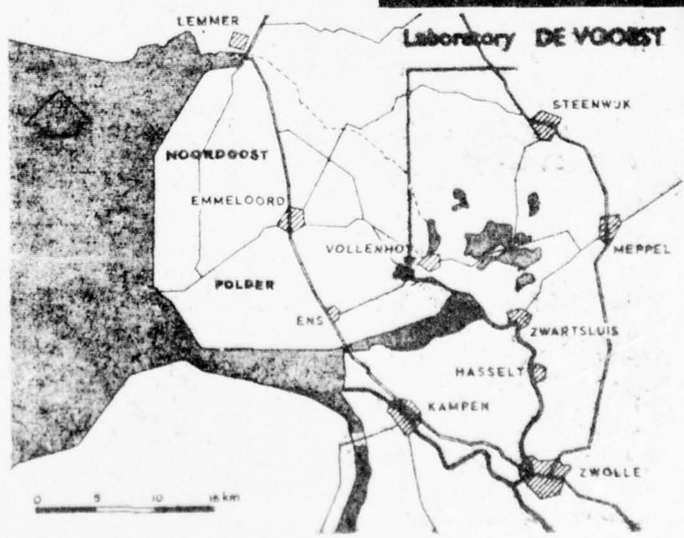
MAP OF DELFT
1 Laboratory
2 Station
3 Tram-stop

Laboratorium DELFT
Raam 61, Delft
telefoon (01730) 24080

Delft Hydraulics Laboratory

Laboratorium DE VOORST
Repelweg, Noordoostpolder
telefoon (05274) 1241





DESCRIPTION AND LAYOUT OF THE "De VOORST" LABORATORY

WINDFLUME BUILDING

1. **WINDFLUME.** Purpose of this windflume is to have a special facility in which to study models of any hydraulic structure opposed to wind and wind-waves. The main effective dimensions are: length 100 m, width 4 m, height 2 m, maximum water-depth 0.8 m, maximum wind-velocity 25 m/s (50 knots), power of the blower 285 kW and maximum water-circulation (opposite to wind-direction only) 3 m^3/s. Preparations are well underway to install a programmed wave-actuator, to meet the latest requirements of offshore engineering.

   The test running now is to determine forces exerted on cylindrical piles opposed to breaking waves. The scale is 1:40; waves with a significant wave-height of 6.65 m are being reproduced.

2. **HIGH-DISCHARGE FLUME.** Models to be subjected to high velocities are built in the test-section of this flume. Maximum discharge amounts to some 10 m^3/s. Effective dimensions are: length 100 m, width 3 m and maximum depth 2.80 m.

   At this moment tests are carried out to determine the erodibility of marine gravel dumped to form a slightly-sloping bed. This gravel is applied in the Europoort-project where deep parts of the sea-bed are locally heightened by dumping large quantities of it. This is a full-scale model; the prototype gravel with a mean size of 1.6 cm is also applied in these tests.

3. **SMALL-DISCHARGE FLUME.** This smaller glass-walled flume is used to study various hydraulic structures not requiring high discharges nor high velocities. The closed-circuit system involves the use of clean water, an advantage compared with the high-discharge flume in which ordinary surface water is used.

   The model built in, is a section of a sluice-caisson placed on a temporary "sill" protected with stones. The scale is 1:30. Sluice-caissons of this type will be applied to close the Northern gap in the Brouwershavense Gat. Tidal currents will be allowed to pass through the caissons and would erode the sill and sea-bed if not protected. Tests have to give directives for the dimensions of the bed protections.

4. FLUME FOR SEDIMENT STUDIES. This small flume is generally used for fundamental studies on bed-load transportation. Main dimensions are: length 30 m, width 0.50 m, maximum depth 0,70 m, maximum discharge 0.12 m^3/s.

A fundamental study is now going on to determine the effect of a local constriction of the flume (0.35 m) on the behaviour of the bed-level, under non-steady conditions of flow. Bed-material used is ground bakelite, mean grainsize 1.7 mm. The non-steady state is a schematized one; conditions are altered daily.

TIDAL-MODEL HALLS

TIDAL MODEL OF "BROUWERSHAVENSE GAT" (M 886). Purpose of this model, built in a hall of 43 x 110 m^2, is to study the sequence of closing the two final gaps in the dam across the Brouwershavense Gat and to determine the flow pattern and maximum current velocities during several stages of the closure. The horizontal-scale is 1:300 and the depth-scale 1:100.
The electronic center containing both the program and recording units is situated in the hall which covers the tidal model of the "Oosterschelde" (M 822), the last closure in the Dutch Delta plan.

At present this model lays idle since both tidal models use the same program and recording unit as well as the same water supply system.

At this moment, the following stage in the model has been attained: the Southern gap is closed (method of gradual closure; concrete cubes have been dumped to fill the whole gap) and in the Northern gap all sluice caissons have been placed (method of caisson closure) but their gates are still opened, allowing tidal currents to pass through. The model is operated automatically; the tide program contains a number of successive tidal curves including a severe storm surge.

OFFSHORE TEST BASIN

The basin is specially designed to study offshore problems. Its main effective dimensions are 25 x 25 m^2, maximum water-depth: 1 m. It is provided with 7 flap-type wave generators which can be made to act separately. Currents can be introduced into three directions: either perpendicular to the wave direction, or in the wave direction (either along with or against the wave). With maximum waterlevel, tidal currents with a velocity of 0.5 m/s can be realized.

Tests now being carried out concern a dam built up of concrete cubes (as part of the Delta-works), of which the stability is determined under the combined action of waves and appreciable difference of water-level at both sides of the dam.

NAVIGATION IN CANALS

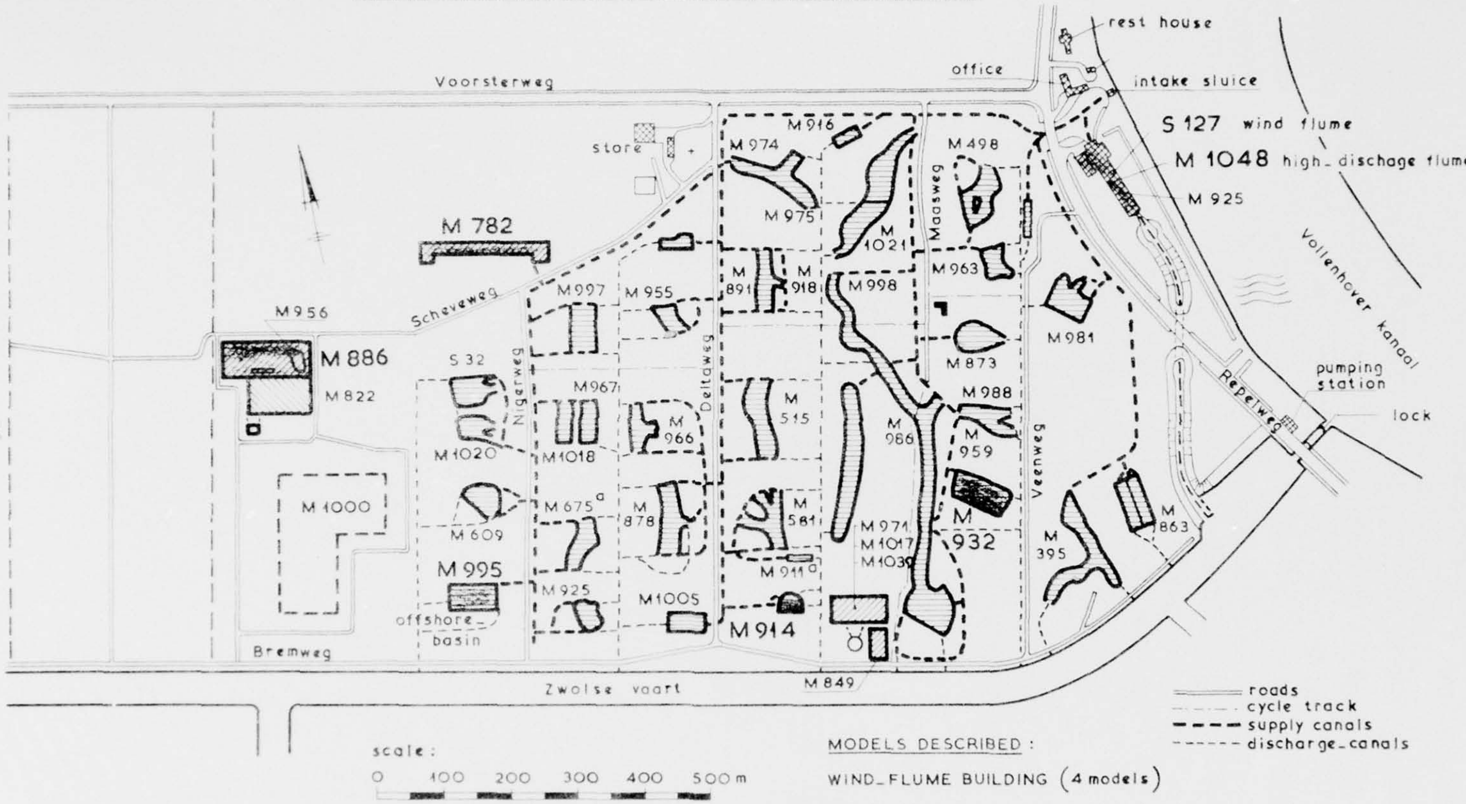
M 782. A straight stretch of canal, housed in a hall of 200 m length, applied to study all hydraulic problems encountered by one or more ships sailing through the canal. Already studied in this model: behaviour of several types of ships when sailing at a certain distance from the canal-banks (inland cargo vessels, ordinary tows, and push-tows), manoeuvres with a combination of one or more types (meeting and passing), and several studies concerning ship waves, translatory waves, and stability of the canal-banks. The scale is 1:25.

OPEN AIR MODELS

1. COASTAL INLET "CANAL DE VRIDI" AT ABIDJAN, IVORY COAST (M 914). This model is to study means of providing sufficient depth in the entrance on behalf of shipping visiting Abidjan-harbour. Due to littoral transport caused by waves only, large quantities of sand are deposited in front of the harbour-mouth. Deepening the entrance will decrease the tidal currents and therefore the depth, an unfavourable condition for shipping. In the model, tidal currents (steady ebb- or steady flood-current), waves, and littoral transport are reproduced. The scales are: horizontal 1:150, depth 1:50.

2. RIVER RHINE AT THE BIFURCATION NEAR PANNERDEN (M 932). As a bend correction in the river Waal (one of the downstream branches) will affect hydraulic and morphological conditions at the bifurcation, a model of this bifurcation will be built to study and solve the problems encountered. Only the part upstream of the bifurcation has been built first, in order to calibrate this separately, thus collecting valuable routine and enabling an economical design for the two branches to be built this summer. The model is supplied with specially-graded sand (that is, any desired particle-size distribution can be arranged) prepared and selected in the nearby sieve-centre. The scales are: horizontal 1:100, depth 1:40.

LAYOUT OF THE " DE VOORST " LABORATORY



MODELS DESCRIBED :

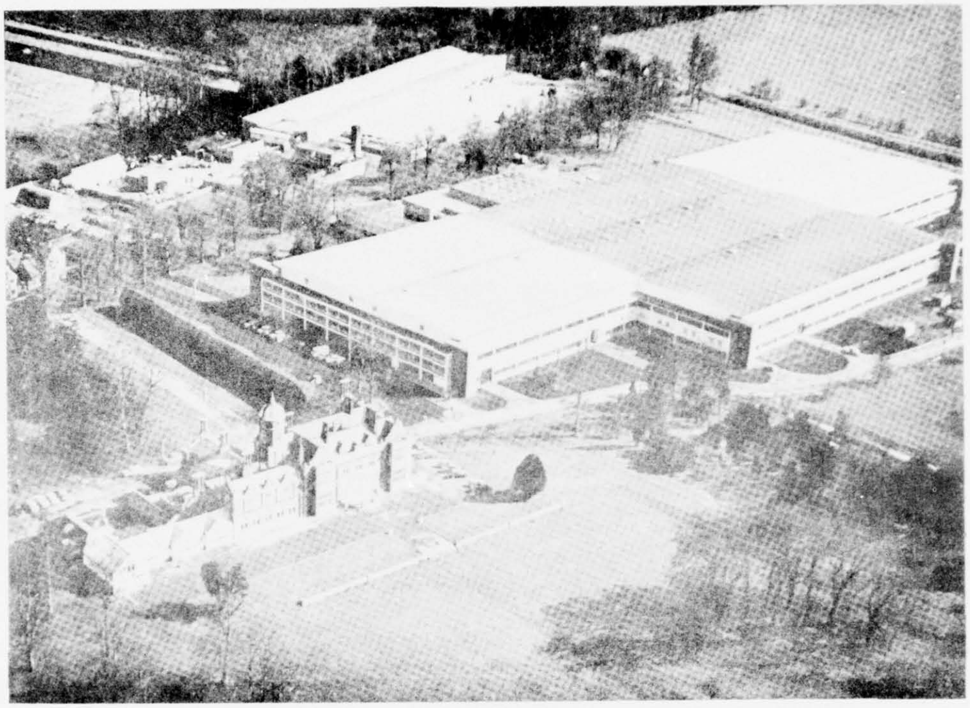
WIND_FLUME BUILDING (4 models)

TIDAL MODELS M 886

OFFSHORE TEST BASIN M955

NAVIGATION IN CANALS M782

OPEN_AIR MODELS M914, M932



HYDRAULICS

RESEARCH STATION

WALLINGFORD

MINISTRY OF TECHNOLOGY

APPENDIX F

THE SCOPE OF THE WORK

The function of the Hydraulics Research Station is to study the behaviour of water flowing in 'open channel' conditions and, in particular, the hydraulic problems encountered in civil engineering. It covers the natural course of water after precipitation on the earth's surface, through drainage into streams and down rivers to the sea. It includes the investigation of problems associated with hydroelectric schemes and flow control structures such as weirs and spillways, the training and control of rivers and estuaries, the development of ports and harbours and the prevention of coast erosion. It does not cover pumps, turbines, flow in pipes under pressure or oil-hydraulics, all of which are the concern of mechanical engineers and are studied by a sister organization, the National Engineering Laboratory at East Kilbride, Glasgow. Other organizations working in neighbouring fields are listed on p. 21.

Despite recent advances in fluid mechanics, it is seldom possible to make full theoretical analyses of flow conditions in civil engineering hydraulic projects, and so scale models are commonly used to obtain basic information for the design of proposed works. Most of the Station's investigations are made into specific engineering problems, related both to the United Kingdom and overseas, and many (though not all) are carried out with the aid of models. These specific investigations are undertaken on repayment mainly for consulting engineers, engineering contractors, industrial concerns, port and harbour trusts and other public bodies including Government departments. A proportion of the Station's effort is also devoted to the study of hydraulic processes encountered in its daily work. These relate to all aspects of open-channel flow and include, for example, unsteady flow in channels and culverts, the transport of sediment in rivers and the mooring of ships under adverse wave conditions.

2. This 1:120 model of Napier Harbour, New Zealand, incorporating one of several proposed improvements, was built in one of the four large wave basins available at the Station for coastal engineering studies.

RESEARCH FACILITIES

A number of permanent facilities are available at the Hydraulics Research Station for investigating specific problems and for research.

The main experimental hall

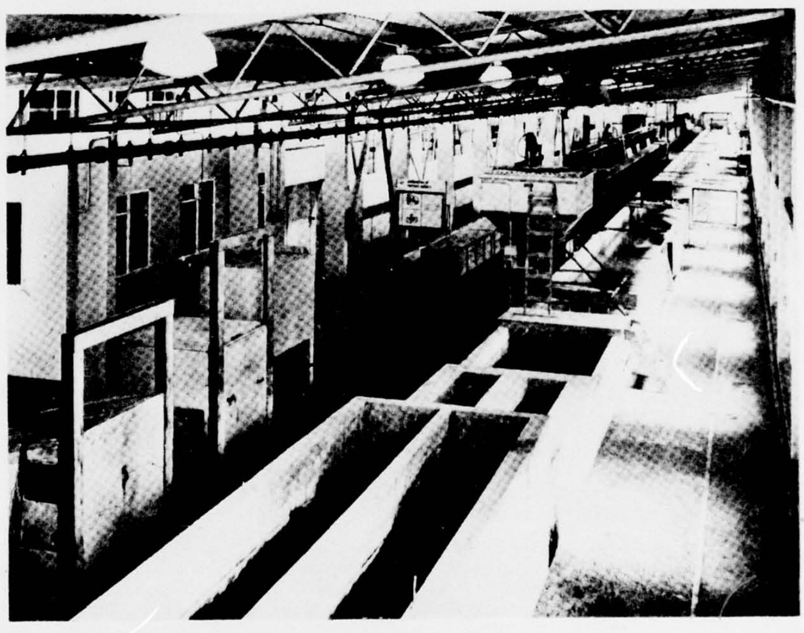
This has been specially designed to house hydraulic models; it has a floor area of 170 000 sq ft (13 000 sq m) interrupted only by eight columns which support the roof. A radiant heating system is installed in the roof. Overhead gantries permit access to any part of a model and there is provision for photographing models through apertures in the ceiling. The floor consists of consolidated earth loosely stabilized so that it can easily be excavated for the construction of models.

Wave basins

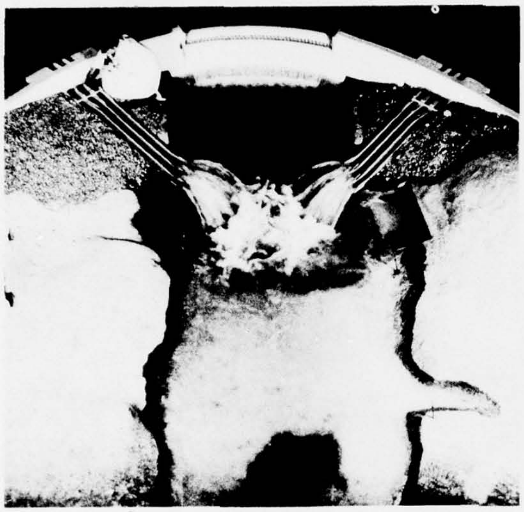
The Station has four large basins for studying wave disturbance problems, for testing harbour designs, for investigating the effects of waves on beaches and for research into sea-defences. All four basins are equipped to produce tides and tidal currents as well as waves; their total area is about 42 000 sq ft (3900 sq m).

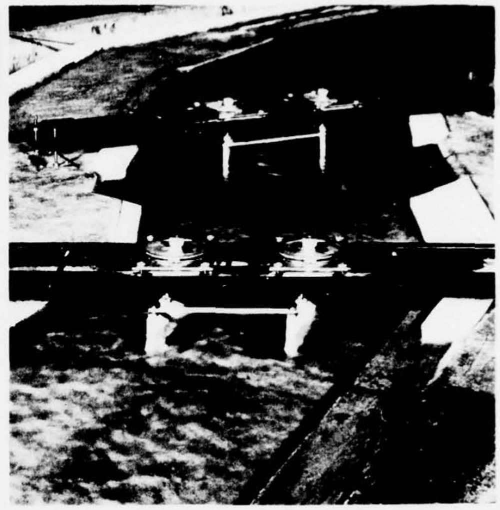
Flumes, channels and tanks

These are an indispensable facility for the research worker in hydraulics and are provided in quantity at the Station. The flumes, two of which can be tilted, range in length from 12 ft (3·6 m) to 400 ft (122 m), and in width from 2 ft (0·6 m) to 12 ft (3·6 m). Four channels are provided with wave-making machinery, one being totally enclosed and fitted with an extractor fan so that wind can be simulated and structures can be tested in the face of random wind-generated waves. A current-meter rating tank is available for the calibration of current meters.



3. Another large building at the Station houses a number of flumes and channels. The flume in the foreground, which is 5 ft (1·5 m) wide and 400 ft (122 m) long, is used for research on the transport of sediment. A second channel, also 400 ft (122 m) long but 12 ft (3·6 m) wide, is used for studies of weir characteristics. Other facilities in this building include a 330-ft (101 m) current-meter rating tank and a 94-ft (29 m) wave channel.





4. This 1/120 model of one of two major dams of the Orange River Project, South Africa, was used to test and develop works for dissipating flood energy and thus minimizing scour of the river bed downstream of the dam.

5. A 1/60 model used to determine the best alignment for the piers of two bridges which it was proposed should be constructed over the River Exe, at Exeter.

OUTLINE OF THE WORK

Collection and appraisal of data

The collection and appraisal of field data is an essential pre-requisite for any model study. Organizations for whom investigations are carried out can usually supply much of the data themselves; the Station does, however, maintain a survey team that collects additional, specialized information when this is required.

Structures

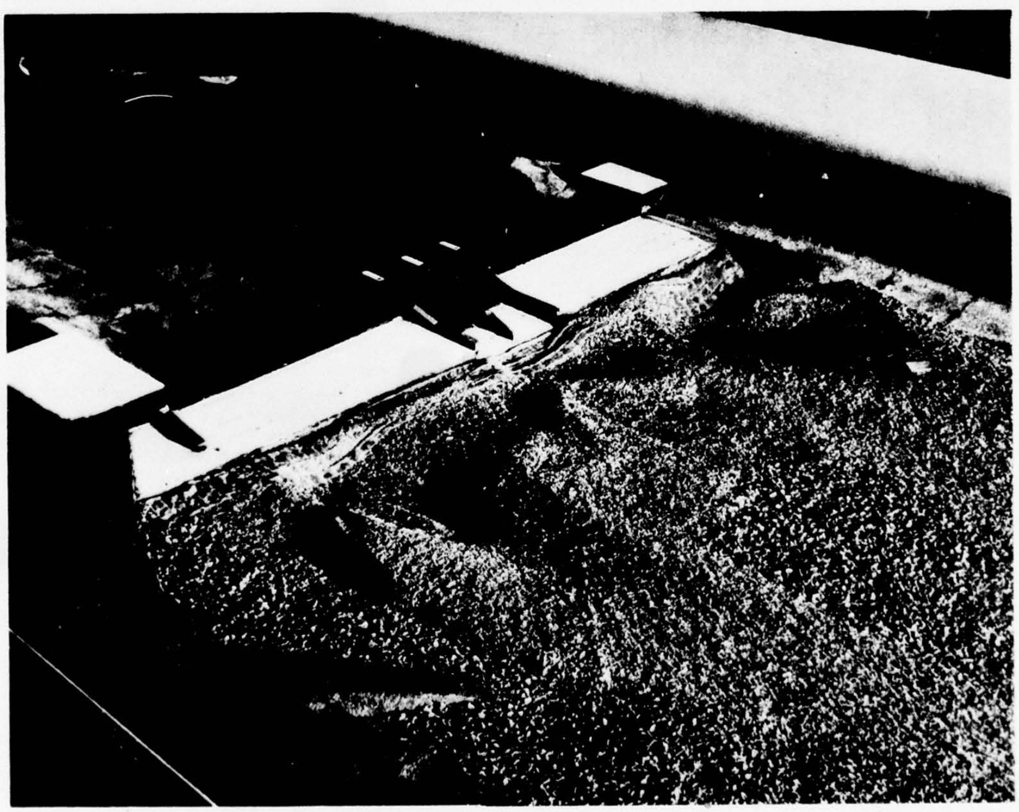
Hydraulic structures necessary to direct and control the flow of water vary in design according to the nature of the project for which they are required. As it is usually impracticable to calculate either the flow characteristics or the forces imposed on the structure in any detail, it is standard practice to study designs by making measurements on scale models; from these tests predictions of considerable accuracy can be made. Structures such as spillways, stilling basins, weirs and sluices are frequently tested at the Station.

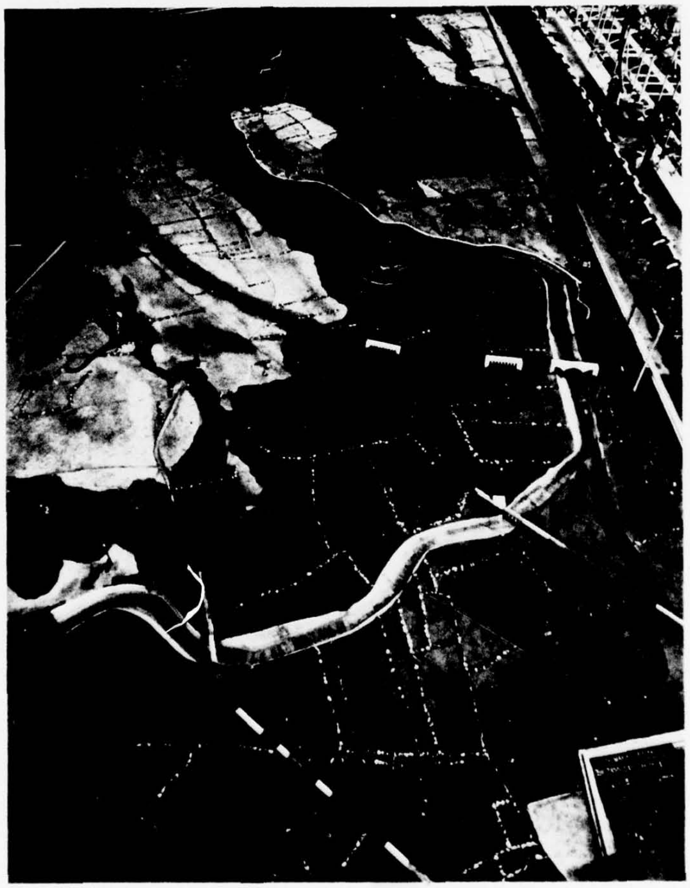
Problem of flooding

In the lower reaches of rivers, where gradients are normally slight, the likelihood of flooding is greater than in the upper reaches. The various ways by which flooding can be reduced—by deepening, widening or straightening channels, by improving weirs and bridges and constructing flood embankments and flood-relief channels—provide the Station with further model investigations. In such models both the river channel and the flood plains bordering it are reproduced.

Allied to the work on improving river channels is the study of how flood levels are affected by embankments carrying roads across flood plains. Openings are provided in these embankments to allow flood water to pass so that the embankment does not cause additional flooding. But these flood arches are expensive to provide, particularly for wide modern motor roads; it is therefore necessary to minimize their number and place them where they will be most effective.

6. Local scour at hydraulic structures can be accurately reproduced on scale models using mobile-bed material. Tests on this model, of Broken Scar Weir, River Tees, enabled appropriate measures to be taken to eliminate scour.





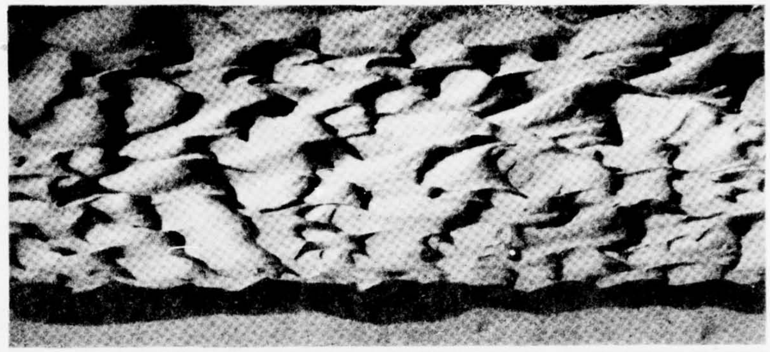
7. Models can provide much useful information on flood levels and flood alleviation schemes. This 1:300 model of part of the River Trent in England reproduced both the river channel and the bordering flood plains. It was constructed to examine the effects of a motorway viaduct on flooding in the valley.

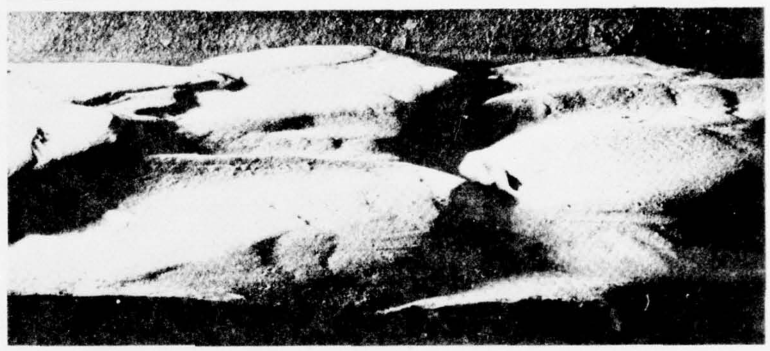
8. Experiments have been conducted in an area of graded sand at the Station to study how the meander pattern of rivers is governed by the quantity of sediment and water in transit. This meander pattern was formed from an originally straight channel fed with water and sediment at a constant rate.

Sediment transport

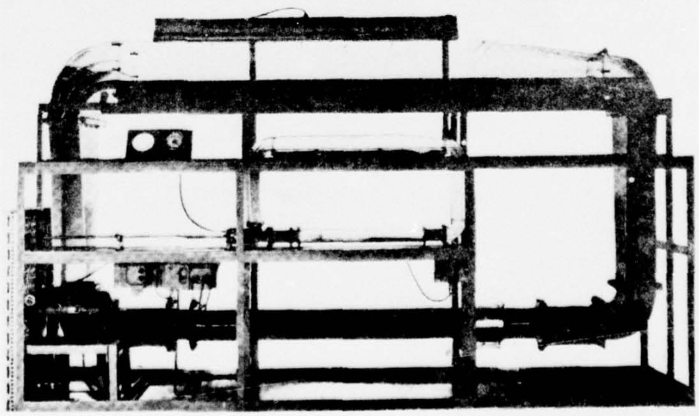
In river studies, and also in work on estuaries and sea coasts, the emphasis is frequently on the movement of sediment by flowing water. This is the most complex part of the Station's work and much of the background research is devoted to it. Investigations so far conducted have included a study of the means of approaching perfect similarity of sediment transport in the laboratory either by steady flow or by wave-motion; also a study of the formation of ripples and dunes, including the influence of channel width; and a study of the slopes and shapes of small channels in alluvium.

The use of radioactive and fluorescent tracers in studies of sediment transport along laboratory channels has enabled techniques to be developed for use of these tracers in the field. Quantitative predictions can now sometimes be made of the siltation rates in projected dredged channels merely from a field investigation of the dispersion of injected tracers.





9. A substantial proportion of the Station's background research is devoted to the study of the transport of sediment by water. Material travelling along the bed forms ripples such as these, which were photographed in the 5-ft flume during experiments on bed transport.

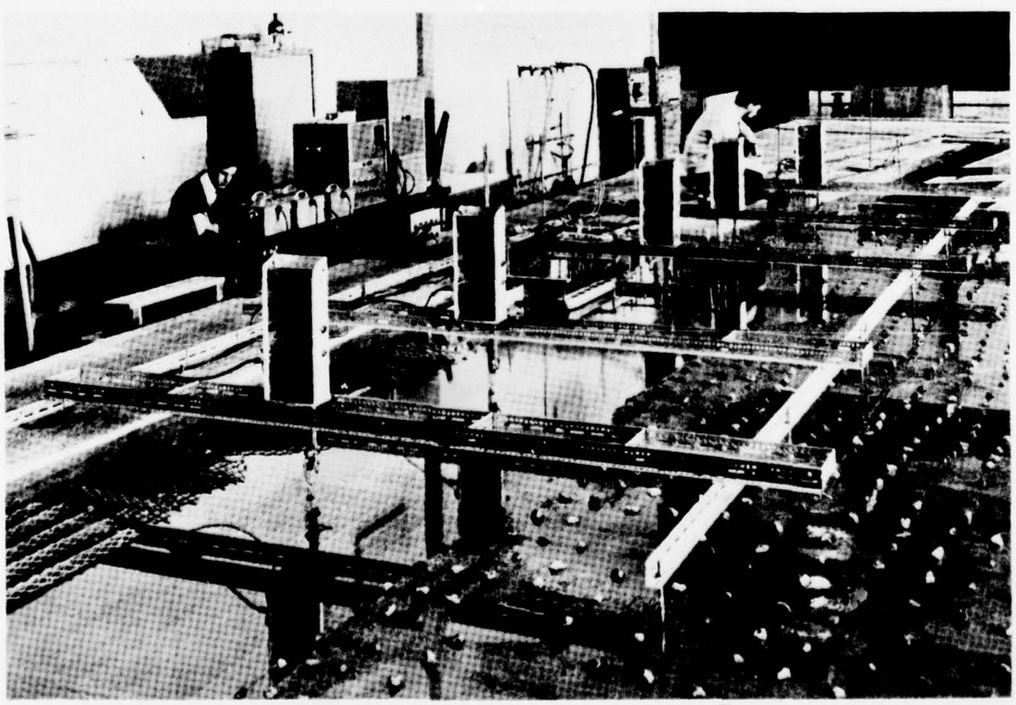


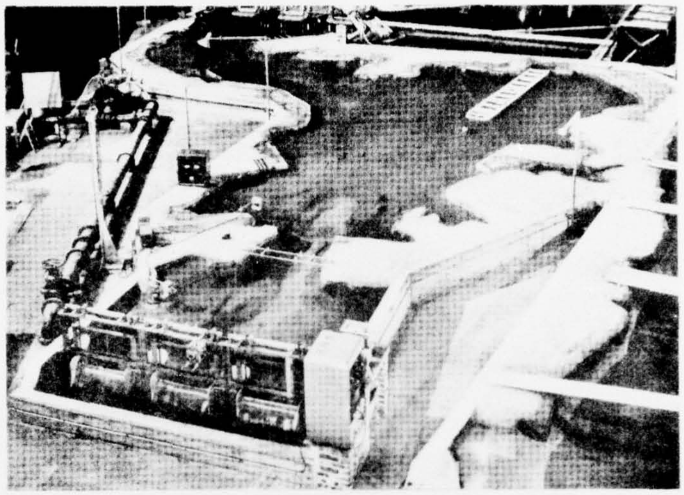
10. Theoretical work at the Station has shown that it is possible (though for day-to-day work impracticable) to obtain perfect dynamic similarity when modelling the processes by which sediment is transported by currents. Two channels, geometrically similar but of different size, have been built to demonstrate this.

Estuaries

Many of the Station's major investigations relate to estuaries in which shoaling, the movement of sediment and the instability of low-water channels have presented serious problems of navigation or dredging. Such investigations are normally made with the aid of large-scale models equipped with servo-controlled mechanisms for reproducing tides through full neap to spring cycles. In some models salinity-density currents and off-shore tidal currents are also reproduced. The Station's Survey Section often gives help with estuary investigations; working from specially equipped boats, a team can collect information on currents, silt movements and salinities, and can carry out experiments using radioactive tracers. Some of these problems are so complex that it is not always possible to arrive at quantitative conclusions. But valuable qualitative and comparative results may be obtained, particularly by workers with extensive experience in this field.

11. A problem frequently investigated at the Station is that of preventing power-station cooling-water being recirculated. In this estuary model (of Dublin Harbour), used for such an investigation, temperatures taken at several different depths and at each of 40 sites were automatically recorded.

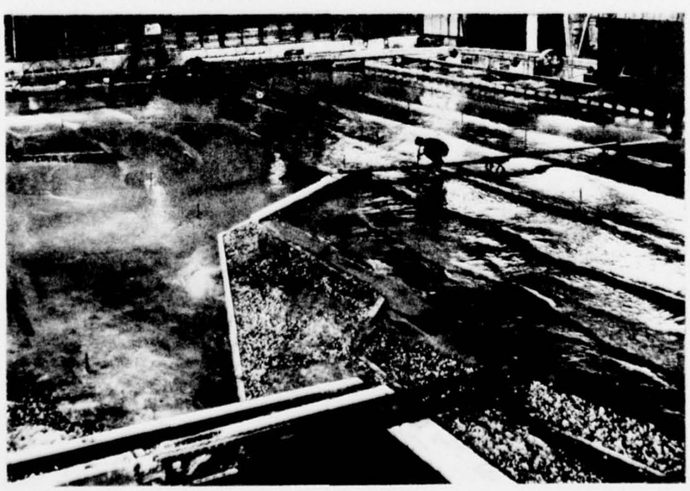




12. Land reclamation in tidal areas can affect the strength and direction of tidal streams. This model of Hong Kong Harbour was constructed to determine the effect on the tidal streams of proposed reclamation schemes. The harbour is situated between Hong Kong island and the mainland and is open to the sea at both ends; thus two tide generators were required in the model.

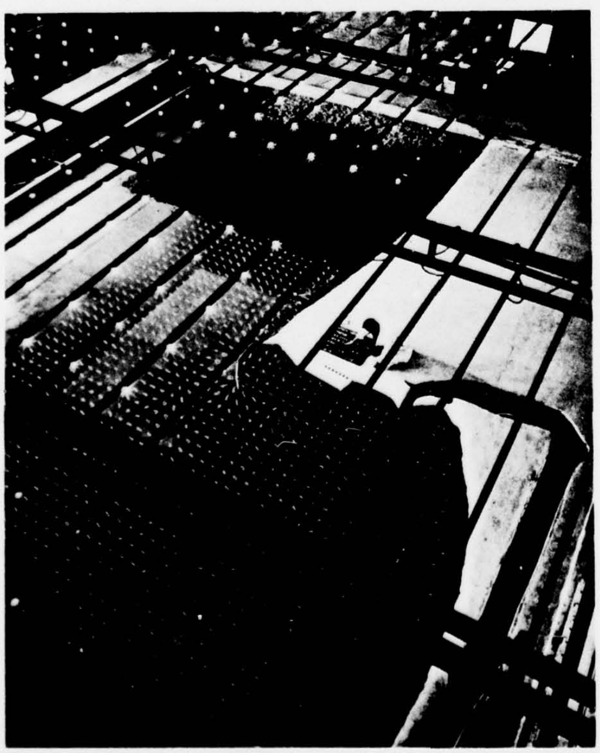
13. Density currents due to differences in salinity are frequently an important factor in the movements of sediment in estuaries. This model of an entrance lock to an oil dock demonstrated the existence of a strong inward-flowing density current when the lock gates were opened.

14. This tidal model of the Tees Estuary was built in Wave Basin No. 2. It was used to determine the feasibility of maintaining, under the action of waves and tidal currents, a deepened channel across the bar at the entrance to the estuary.



Wave disturbance problems and the sea coast

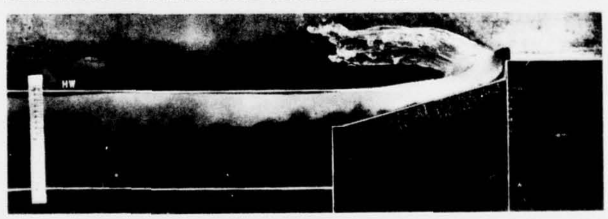
On the coast, the Station is confronted with two main types of investigation, those dealing solely with wave motion and the forces imposed by waves, and those concerned with transport of sand and shingle. In the first group are studies of the performance of sea walls and breakwaters under wave action, the design of harbours (to determine their effectiveness in protecting shipping from wave action) and, in certain circumstances, the behaviour of moored ships under wave action. In the second group are studies of coastal erosion, the formation of sand-bars and the shoaling of dredged channels. Much of the work in both groups is carried out on a repayment basis, but that concerning sea defence problems consists mainly of studies undertaken (under the guidance of an interdepartmental committee) as part of the Station's own research programme. Research has been conducted into the design of groynes, the problem of erosion downdrift of the last groyne and into means of measuring the littoral drift of sand and shingle. A knowledge of the quantity of littoral drift is necessary for a correct assessment of the value of groynes and the Station has developed fluorescent tracers for this purpose.



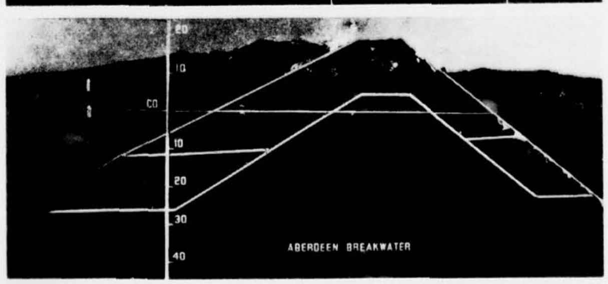
15. Long-period waves, which are often difficult to detect in harbours, can cause ships to move about at their moorings. To test whether proposed harbour designs will be effective in excluding them, long-period waves are reproduced in a model. Numerous points of light on a ceiling, reflected by the water surface, are photographed with an exposure time equal to one wave-period and the length of the trace indicates the maximum slope of the water surface. By providing a measure of the horizontal movement of the water, this indicates the extent by which a ship would be moved.

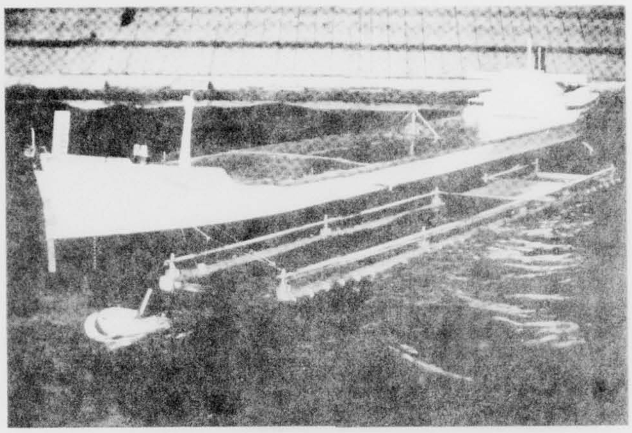
16. *The Station's Wave Section deals with many aspects of wave action. Fundamental research has included studies of the secondary drift due to waves, using luminous particles to demonstrate the orbital motion.*

17. *Sea walls can be tested to determine the amount of over-topping by waves and their continued effect on beach levels, as in the case of a 1/20 model of the sea wall at Portobello in Scotland. For these tests a short length of the proposed sea wall was reproduced to scale in the 94-ft Wave Channel.*



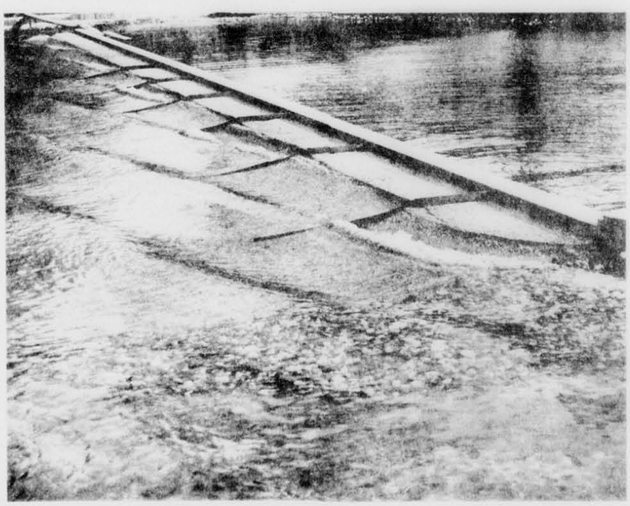
18. *Models of short lengths of rubble-mound breakwaters are tested in wave channels to study over-topping and the stability of the section. The breakwater illustrated was for Aberdeen Harbour, Hong Kong.*





19. Oil tankers are nowadays built so large that many ports cannot accommodate them. One solution is to moor them to a fixed tower or floating buoy positioned outside the port and to pump the oil ashore from there. In this model a supertanker is being subjected to variable winds, waves and currents, and the forces on the buoy are being determined.

20. As the factors affecting the stability of beaches are many and complex, it is often impracticable to study the behaviour of beaches in nature. In models, however, the various factors can be controlled and their effects isolated. In these studies of the effects of groynes on sandy and shingle beaches, waves, tides and tidal currents can be reproduced and varied within a wide range.



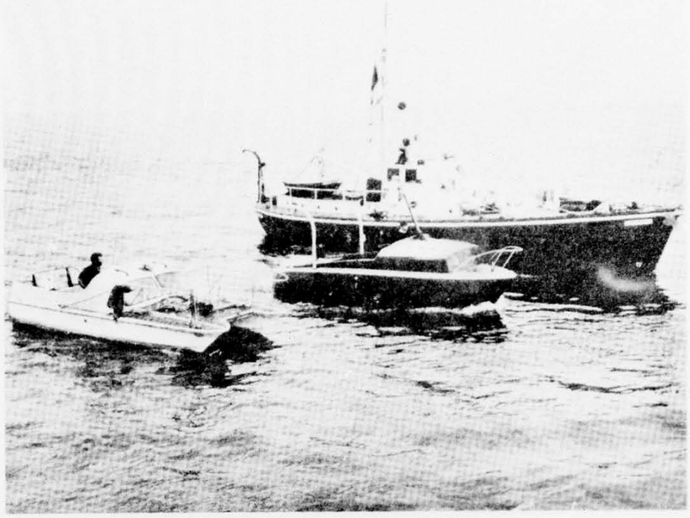
SERVICE SECTIONS

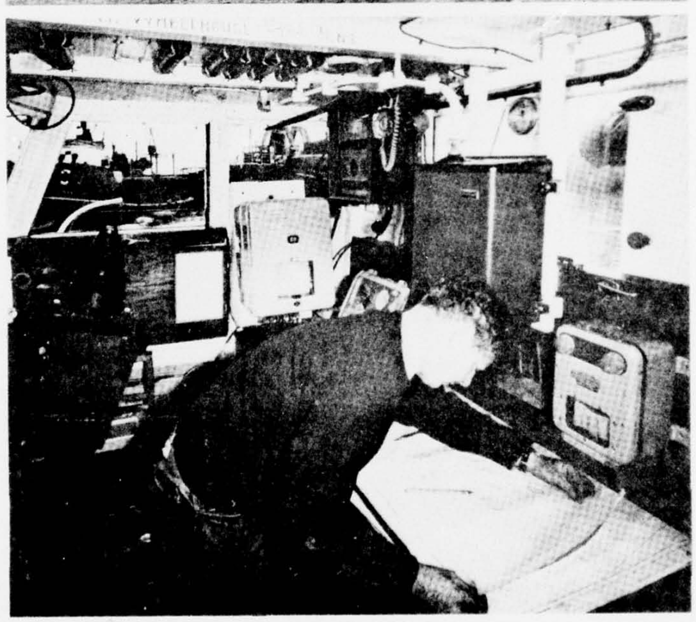
One of the advantages enjoyed by the Station is that it is large enough to maintain specialist service sections. The Electrical and Mechanical Engineering Section, for instance, makes full use of modern techniques in the design of instruments, automatic control systems and plant; data logging is used where applicable and models are provided with a wide range of instruments and efficient automatic devices for the control of flow and the reproduction of tides.

A computer unit is available to tackle those problems that are amenable to mathematical analysis, and to provide a general computing service for the station.

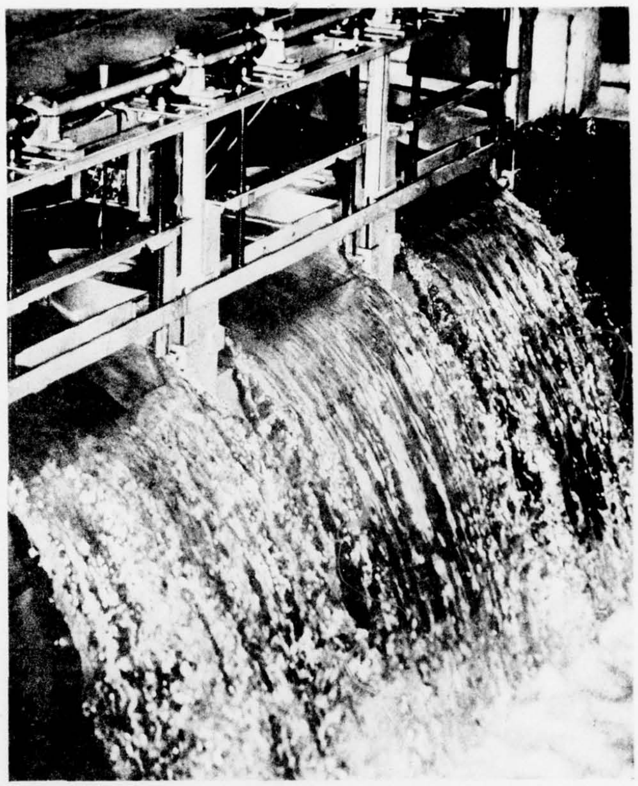
Other service sections include a modern and well-equipped machine workshop, a wood workshop, a unit for the construction of models, a sedimentation laboratory, a drawing office and a photographic department. The survey section has already been mentioned on pages 5 and 10.

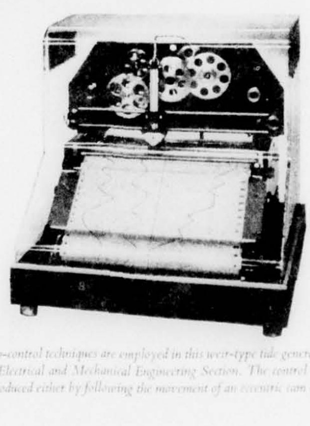
21. A knowledge of the size-distribution of sediments is essential in all studies of sediment transport. The laboratory illustrated in this view is devoted mainly to analysis of particle size.



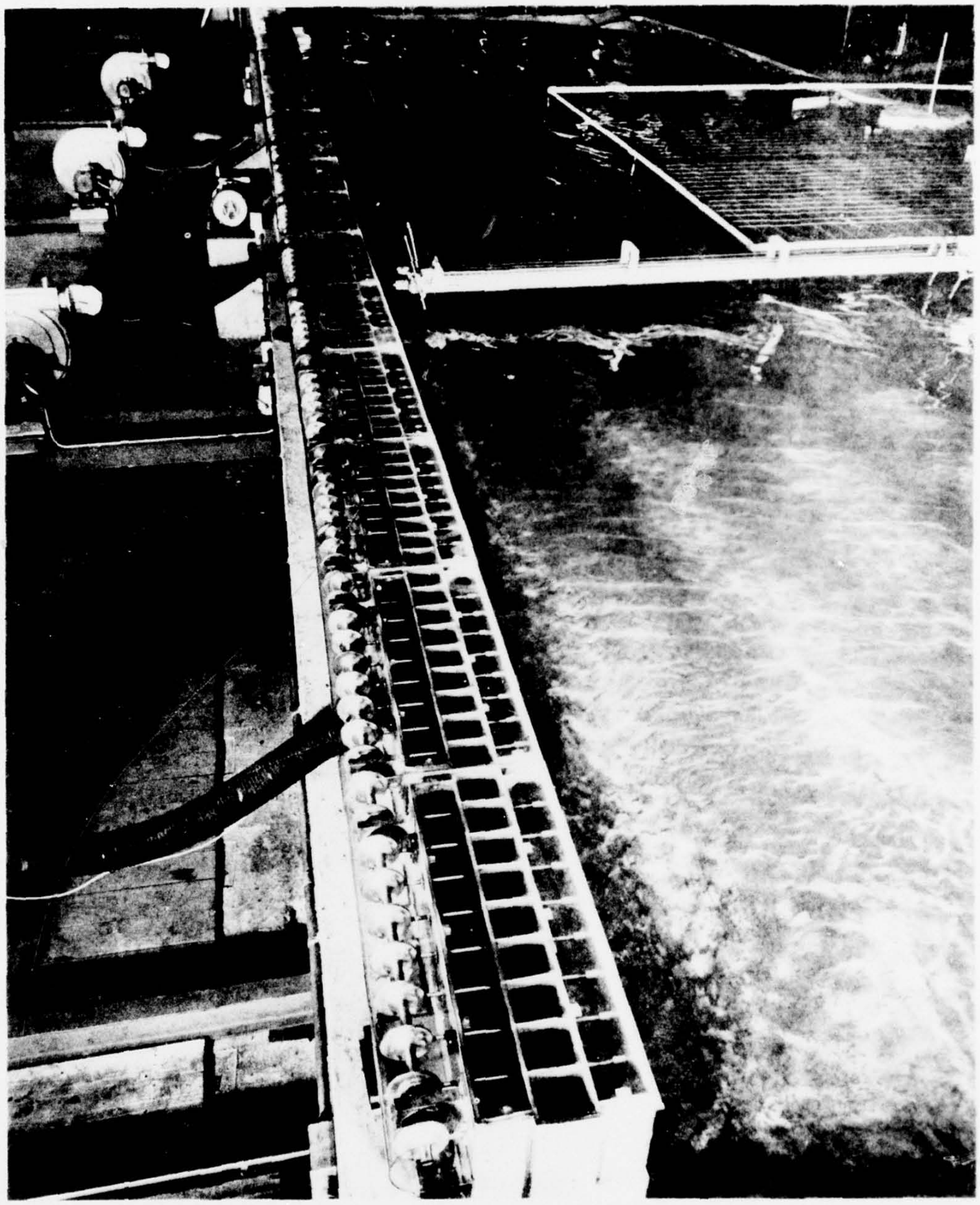


22. Although organizations requesting hydraulic investigations can usually supply much of the prototype data required, it is often necessary for the Station's Survey Team to collect additional specialized information. The Team is fully equipped for this purpose. Three of the Team's craft are seen here, together with an interior view of the largest vessel.

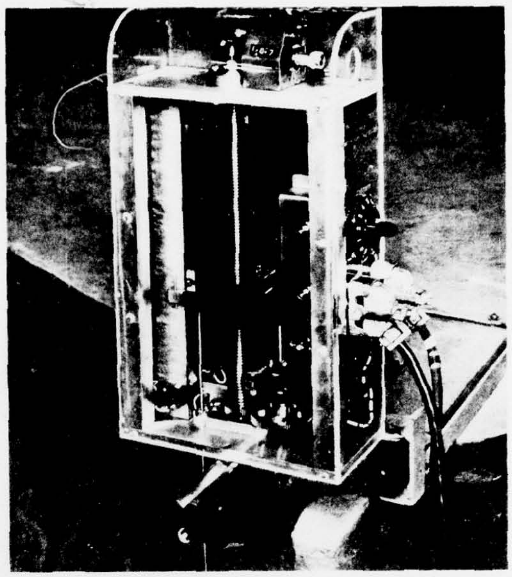




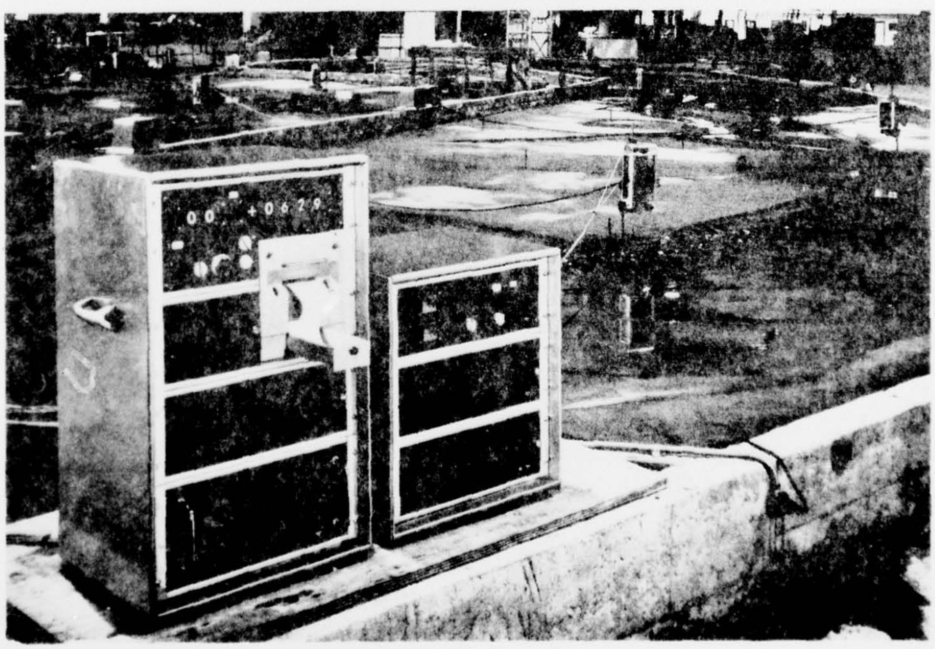
23. Modern servo-control techniques are employed in this weir-type tide generator designed and constructed by the Station's Electrical and Mechanical Engineering Section. The control systems permit whole cycles of tides to be reproduced either by following the movement of an eccentric cam or by following a previously drawn curve.

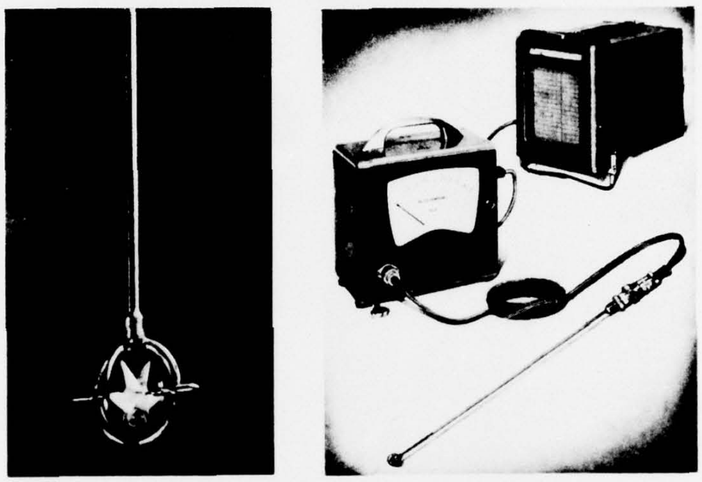


24. This pneumatic wave-maker is capable of producing waves over a wide range of angles to the shore line. It is cheap to make, can be built in sections to any length, occupies little space in the model and can be moved easily from one model to another.

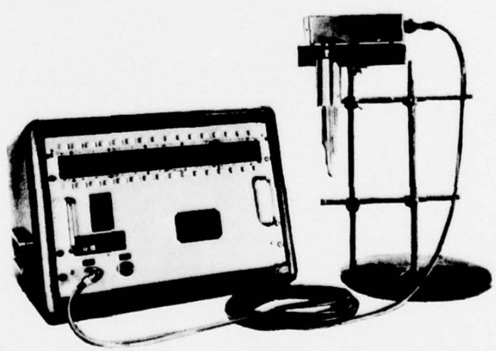


25. *A Station instrument that has been made in large numbers is this automatic water level transmitter which accurately indicates a varying water level and also transmits the measurement to a 100-channel data logger. Below the data logger is shown in position on a model.*





26. Miniature propeller current meters (with 4, 10 and 20-mm rotors) have been developed by the Station's instrument engineers to fulfil a need for a sensitive current meter causing minimum interference to flow patterns. The instrument will measure velocities down to about 0·7 in/sec.



27. This instrument uses logic circuits to measure and classify the individual heights of a selected train of model waves into 32 discrete incremental groups. It also registers the total number of waves in each group.

Investigations of specific problems. Advice and information

A charge is normally made for investigating specific problems, the charge being dependent on the amount of staff time and other costs involved. Advice is however given free of charge where this is practicable. The Station is always willing to provide an estimate of the cost of investigating a specific problem and to supply details of the contractual conditions under which the work would normally be carried out.

The Station's Library, which contains an extensive collection of hydraulic literature, is available for use by those interested.

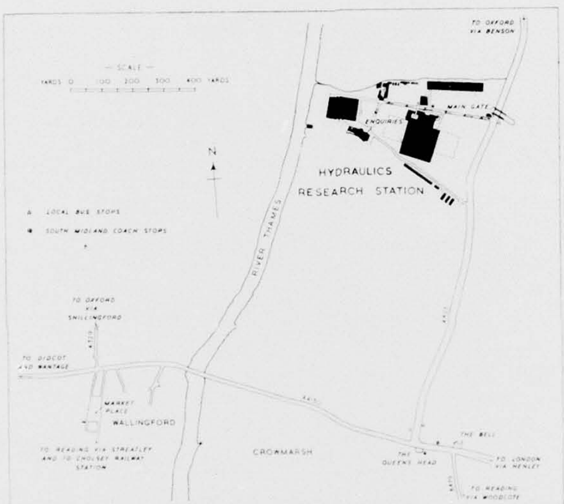
Organization

The Hydraulics Research Station is one of a number of Research Stations of the Ministry of Technology; these laboratories cover a wide range of subjects in science and engineering.

The Station is headed by the Director of Hydraulics Research who is responsible both for its scientific work and administration. There is a Steering Committee, of which the Director is a member, and a number of specialist advisory committees. The total staff of the Station numbers about 230, of which those engaged directly on research are mostly civil engineers; others are qualified in physics, mathematics, mechanical engineering, electrical engineering and geography. The annual budget is about £350 000.

Co-operation with other organizations

The Station works in close co-operation with Government departments that have interests in the same field. Among these are the Ministry of Land and Natural Resources; the Ministry of Agriculture, Fisheries and Food; the Ministry of Overseas Development; the Ministry of Housing and Local Government; the Natural Environment Research Council; the Ministry of Transport and the Ministry of Defence. It also enjoys good relations with research organizations working in allied fields, and with them avoids wasteful duplication of effort. These organizations include the Fluid Mechanics Division of the National Engineering Laboratory (see p. 2), the British Hydromechanics Research Association (whose work lies between that of the Station and that of the National Engineering Laboratory), the Water Pollution Research Laboratory, the Nature Conservancy (which keeps lengths of coastline under observation and studies beach protection from the botanical point of view), and the National Institute of Oceanography (which is interested in the seas rather than the coasts).



Public transport to the Hydraulics Research Station

Rail

The nearest railway station is at Cholsey, which is about 3 miles from the Hydraulics Research Station. Cholsey is on the main line from Paddington Station in London, but it is often necessary to change at Reading. Buses from Cholsey station pass the Station, but they are infrequent and it is normally possible to provide visitors with official transport from Cholsey.

London–Crowmarsh–Oxford Coach Service

The 2-hourly South Midland coach service between London (Victoria Coach Station) and Oxford, via Maidenhead, Henley and Crowmarsh, passes the main gate of the Hydraulics Research Station. It is normally necessary to reserve tickets in advance on these coaches.

Local Bus Services

The hourly bus service between Reading and Oxford also passes the main gate of the Hydraulics Research Station. This service is run jointly by Oxford City Motor Services and the Thames Valley Traction Co. There are also irregular services to and from Abingdon, Didcot and Henley.

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